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# Ballistic Evaluation of 7056 Aluminum

by Denver B Gallardy

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by Denver B Gallardy

*Weapons and Materials Research Directorate, ARL*

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<b>14. ABSTRACT</b> The US Army Research Laboratory evaluated the ballistic performance of aluminum alloys (AAs) 7056-T761, 7056-T751, and 7056-T721 produced by Constellium. Ballistic evaluation was performed using armor-piercing and fragment-simulating projectiles to determine the V <sub>50</sub> ballistic-protection limit (V <sub>50</sub> ) for various thicknesses of material. The V <sub>50</sub> was then compared with other ballistic-grade AAs, namely AA7085-T711 and AA7085-T721. The results of these experiments were used to validate the acceptance tables for AA7085 and AA7056 included in the updated military specification, MIL-DTL-32375A (MR).					
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## 1. Introduction

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Aluminum alloy (AA) 7056 is Constellium's next-generation armor offering that can be sourced both domestically and through North Atlantic Treaty Organization member countries. Two tempers were developed: 1) a high-strength variant, 7056-T761, for use as an appliqué against direct-fire threats and 2) a lower strength, higher ductility variant, 7056-T721, for underbody blast protection kits. AA7056-T761 is currently in competition to be used in several Army platforms including the Bradley, Joint Light Tactical Vehicle, and Armored Multi-Purpose Vehicle.

The ballistics goal of this program was to verify that AA7056-T761 and AA7056-T721 met or exceeded the performance of comparable military-specification (mil-spec) 7XXX-series alloy produced by Alcoa, namely 7085-T711 and 7085-T721.<sup>1</sup> The results were used to subsequently add 7056 to the 7085 specification, allowing increased availability of material and pricing competition to benefit the Army. In addition to the 2 tempers outlined for the mil-spec, a third temper, 7056-T751, was also assessed. AA7056-T751 was the original blast temper but was modified slightly during the evaluation period warranting the updated 7056-T721 designation. The properties of the 7056-T751 evaluated were very similar to the 7056-T721 temper, and therefore the data were combined during analysis. Table 1 outlines the average mechanical properties for the evaluated samples.

**Table 1 Average mechanical properties of evaluated plates**

Alloy/ temper	Direction	Ultimate tensile strength (MPa)	Yield strength, 0.2% offset (MPa)	Elongation (%)	Direction	Ultimate tensile strength (MPa)	Yield strength, 0.2% offset (MPa)	Elongation (%)
7056- T721	L	495.8	446.8	15.0	LT	497.1	442.0	12.9
7056- T751	L	494.5	455.2	14.5	LT	510.3	457.3	12.3
7056- T761	L	568.8	547.5	11.5	LT	573.9	541.0	9.9

Note: L = longitudinal; LT = long transverse

Several thicknesses of the temper variants were provided to the US Army Research Laboratory (ARL) by Constellium. Table 2 is a summary matrix of the evaluated thicknesses subjected to impacts from various munitions including armor-piercing (AP) and fragment-simulating projectiles (FSPs). Additionally, Table 3 provides the required chemistries for AA7056 as well as other common aluminum (Al) armor alloys.

**Table 2 Experimental matrix for the AA7056 tempers indicating the number of plates evaluated**

Nominal plate gage (mm)	0.30-cal. APM2 0° obliquity		0.50-cal. APM2 0° obliquity		14.5-mm BS41 0° obliquity		0.50-cal. FSP 0° obliquity		20-mm FSP 0° obliquity	
	T761	T721/ T751	T761	T721/ T751	T761	T721/ T751	T761	T721/ T751	T761	T721/ T751
22.23	1	2	...	...	...	...	1	2	1	2
25.40	1	1	...	...	...	...	...	1	1	1
38.10	3	2	2	5	...	...	...	...	3	2
41.28	...	2	...	...	...	...	...	...	...	2
50.80	...	...	1	1	...	...	...	...	...	...
57.15	...	...	...	...	...	...	...	...	...	...
63.50	...	...	2	4	2	4	...	...	...	...
76.20	...	...	...	2	1	2	...	...	...	...

**Table 3 Chemistry of AAs, weight-percent ranges<sup>2</sup>**

<b>Element</b>	<b>5083</b>	<b>6061</b>	<b>2139</b>	<b>2195</b>	<b>2060</b>	<b>7017</b>	<b>7085</b>	<b>7056</b>
Copper	0.10 max	0.15–0.40	4.5–5.5	3.70–4.30	3.40–4.50	0.20 max	1.3–2.0	1.2–1.9
Iron	0.40 max	0.70 max	0.15 max	0.15 max	0.07 max	0.45 max	0.08 max	0.12 max
Lithium	...	...	...	0.80–1.20	0.60–0.90	...	...	...
Chromium	0.05–0.25	0.04–0.35	0.05 max	...	...	0.35 max	0.04 max	...
Manganese	0.40–1.0	0.15 max	0.20–0.60	0.25 max	0.10–0.50	0.05–0.50	0.04 max	0.20 max
Magnesium	4.0–4.90	0.8–1.2	0.20–0.80	0.25–0.80	0.60–1.10	2.0–3.0	1.2–1.8	1.5–2.3
Silicon	0.40 max	0.40–0.80	0.10 max	0.12 max	0.07 max	0.35 max	0.06 max	0.10 max
Titanium	0.15 max	0.15 max	0.15 max	0.10 max	0.10 max	0.15 max	0.06 max	0.08 max
Zinc	0.25 max	0.25 max	0.25 max	0.25 max	0.30–0.50	4.0–5.2	7.0–8.0	8.5–9.7
Zirconium	...	...	...	0.08–0.16	0.05–0.15	0.10–0.25	0.08–0.15	0.05–0.15
Silver	...	...	0.15–0.60	0.25–0.60	0.05–0.50	...	...	...
Others (each)	0.05 max							
Others (total)	0.15 max							
Aluminum	Remainder							

## **2. Experimental Procedure**

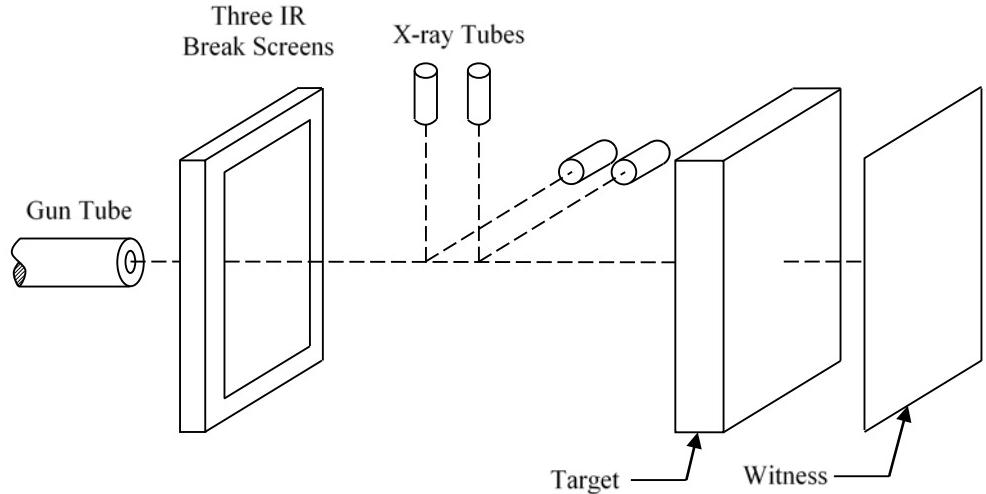
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The  $V_{50}$  is defined as the impact velocity at which the projectile is equally as likely to perforate the target as it is to be arrested. A 0.51-mm (0.020 inch) 2024 T3 Al witness plate was positioned 152 mm (6 inches) behind the target to determine the outcome of each shot. An impact is regarded as a complete penetration (CP), or loss, if the projectile or a resulting target fragment from impact creates a hole in the witness plate through which light can be observed. If an impact does not result in a CP, it is considered a partial penetration (PP), or win. To keep results as consistent as possible, only shots conforming to the following conditions were used to determine the  $V_{50}$ : The projectile must be unyawed—less than  $2^\circ$  of total yaw for AP rounds and less than  $5^\circ$  of total yaw for FSPs—and strike the target at least 2 projectile diameters from any previous impact or damage or the edge of the target. Total yaw is defined as the vector sum of the projectile's pitch and yaw. The  $V_{50}$  is calculated by the arithmetic mean of an equal number of CPs and PPs within an 18-m/s (60 ft/s) spread for a  $2 + 2 V_{50}$ , a 27-m/s (90 ft/s) spread for a  $3 + 3 V_{50}$ , and as small of a spread as attainable for a  $5 + 5 V_{50}$ .<sup>3</sup>

Projectile velocities for the determination of the  $V_{50}$  were measured using one of 2 methods, as shown in Fig. 1. The first method is an orthogonal flash X-ray system, described in detail by Grabarek and Herr,<sup>4</sup> that also measures pitch and yaw. The second method uses 3 IR screens and a chronograph. The velocity is calculated using the first and third screens with the middle screen used to check for bad readings. The flash X-ray method was used in situations with projectiles that historically exhibit excessive yaw or if space did not allow for the use of the IR break screens. When the IR break screens and chronograph were used, the projectile velocity was corrected to the target-impact location using a correction factor based on an initial flash X-ray reading at the impact location. The correction was made using Eqs. 1 and 2 in lieu of using air-drag factors.

$$\frac{(\text{x-ray velocity})}{(\text{chronograph velocity})} = (\text{correction factor}). \quad (1)$$

$$(\text{correction factor}) \times (\text{chronograph velocity}) = (\text{corrected velocity}). \quad (2)$$



**Fig. 1** Typical experimental setup

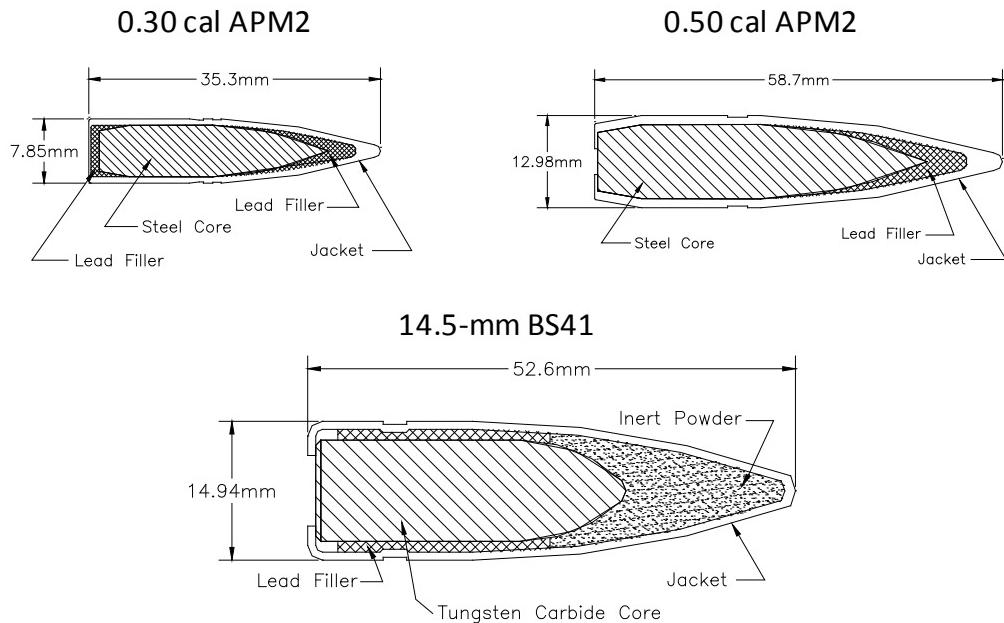
### 3. Experimental Projects

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#### 3.1 Armor-Piercing Projectiles

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The US 0.30-cal. APM2 and 0.50-cal. APM2 plus the Soviet 14.5-mm BS41 are the 3 AP projectiles that were used in this study. These projectiles are shown in Fig 2. The APM2 projectiles have hardened steel cores with a Rockwell hardness of C61-63, whereas the BS41 has a tungsten carbide core. The physical characteristics of these projectiles are listed in Table 4.



**Fig. 2** AP projectiles

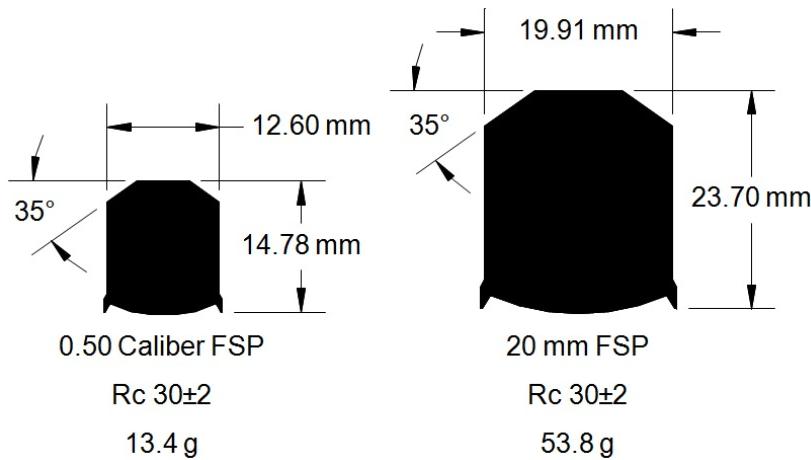
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**Table 4 AP projectiles' physical characteristics<sup>5</sup>**

Projectile type	Projectile			Core		
	Length (mm)	Diameter (mm)	Weight (g)	Length (mm)	Diameter (mm)	Weight (g)
0.30-cal. APM2	35.3	7.85	10.8	27.4	6.2	5.3
0.50-cal. APM2	58.7	12.98	45.9	47.5	10.9	25.9
14.5-mm BS41	52.6	14.94	63.2	32.3	10.9	37.9

### **3.2 Fragment-Simulating Projectiles**

FSPs (Fig. 3) are a family of projectiles that are flat-nosed, right circular cylinders manufactured to MIL-DTL-46593B (MR).<sup>6</sup> These projectiles are used in material evaluations and acceptance testing to simulate performance against fragments produced from improvised explosive devices and artillery. Both 0.50-cal. and 20-mm FSPs were used for the evaluation of AA7056.



**Fig. 3 FSP projectiles**

## **4. Results and Analysis**

The experimental results are summarized in Tables 5–14. The individual shot records are provided in Appendix A and Appendix B.

**Table 5 APM2 0.30-cal., 0° obliquity V<sub>50</sub> ballistic limits for AA7056-T761**

Plate ID	Nominal thickness		Actual thickness		Areal density		V <sub>50</sub>		Standard deviation	
	(mm)	(inches)	(mm)	(inches)	(kg/m <sup>2</sup> )	(lb/ft <sup>2</sup> )	(m/s)	(ft/s)	(m/s)	(ft/s)
823551	22.23	0.88	22.68	0.893	65.10	13.33	677	2221	7	23
823551	25.40	1.00	28.02	1.103	80.41	16.47	764	2508	7	22
823531	38.10	1.50	36.75	1.447	105.48	21.60	893	2931	8	26
900305	38.10	1.50	37.77	1.487	108.40	22.20	906	2972	5	18
823531	38.10	1.50	40.59	1.598	116.49	23.86	939	3081	6	22

**Table 6 APM2 0.50-cal., 0° obliquity V<sub>50</sub> ballistic limits for AA7056-T761**

Plate ID	Nominal thickness		Actual thickness		Areal density		V <sub>50</sub>		Standard deviation	
	(mm)	(inches)	(mm)	(inches)	(kg/m <sup>2</sup> )	(lb/ft <sup>2</sup> )	(m/s)	(ft/s)	(m/s)	(ft/s)
823531	38.10	1.50	36.75	1.447	105.48	21.60	656	2153	8	25
900305	38.10	1.50	37.77	1.487	108.40	22.20	651	2135	5	15
823531	38.10	1.50	40.64	1.600	116.64	23.89	692	2271	6	20
900294	50.80	2.00	49.28	1.940	141.42	28.97	776	2545	5	17
823541	63.50	2.50	65.23	2.568	187.20	38.34	916	3006	7	22
823561	63.50	2.50	65.35	2.573	187.57	38.42	928	3046	6	20

**Table 7 14.5-mm BS41, 0° obliquity V<sub>50</sub> ballistic limits for AA7056-T761**

Plate ID	Nominal thickness		Actual thickness		Areal density		V <sub>50</sub>		Standard deviation	
	(mm)	(inches)	(mm)	(inches)	(kg/m <sup>2</sup> )	(lb/ft <sup>2</sup> )	(m/s)	(ft/s)	(m/s)	(ft/s)
823541	63.50	2.50	65.20	2.567	187.13	38.33	846	2777	6	19
823561	63.50	2.50	65.35	2.573	187.57	38.42	860	2823	5	17
900293	76.20	3.00	77.60	3.055	222.70	45.61	934	3065	8	26

**Table 8 FSP 0.50-cal., 0° obliquity V<sub>50</sub> ballistic limits for AA7056-T761**

Plate ID	Nominal thickness		Actual thickness		Areal density		V <sub>50</sub>		Standard deviation	
	(mm)	(inches)	(mm)	(inches)	(kg/m <sup>2</sup> )	(lb/ft <sup>2</sup> )	(m/s)	(ft/s)	(m/s)	(ft/s)
823551	22.23	0.88	22.68	0.893	65.10	13.33	846	2774	5	19

**Table 9 FSP 20-mm, 0° obliquity V<sub>50</sub> ballistic limits for AA7056-T761**

Plate ID	Nominal thickness		Actual thickness		Areal density		V <sub>50</sub>		Standard deviation	
	(mm)	(inches)	(mm)	(inches)	(kg/m <sup>2</sup> )	(lb/ft <sup>2</sup> )	(m/s)	(ft/s)	(m/s)	(ft/s)
823551	22.23	0.88	22.68	0.893	65.10	13.33	360	1180	14	45
823551	25.40	1.00	28.02	1.103	80.41	16.47	522	1711	4	15
823531	38.10	1.50	36.75	1.447	105.48	21.60	870	2854	7	23
900305	38.10	1.50	37.77	1.487	108.40	22.20	880	2887	7	23
823531	38.10	1.50	40.59	1.598	116.49	23.86	986	3234	4	14

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**Table 10 APM2 0.30-cal., 0° obliquity V<sub>50</sub> ballistic limits for AA7056-T751 and AA7056-T721**

Plate ID	Plate temper	Nominal thickness		Actual thickness		Areal density		V <sub>50</sub>		Standard deviation	
		(mm)	(inches)	(mm)	(inches)	(kg/m <sup>2</sup> )	(lb/ft <sup>2</sup> )	(m/s)	(ft/s)	(m/s)	(ft/s)
649471	T721	22.23	0.88	22.66	0.892	65.03	13.32	659	2161	5	18
647911	T751	22.23	0.88	22.86	0.900	65.61	13.44	629	2065	7	21
647911	T751	25.40	1.00	26.01	1.024	74.65	15.29	691	2268	6	19
649461	T721	38.10	1.50	36.70	1.445	105.34	21.57	839	2753	7	24
647921	T751	38.10	1.50	36.80	1.449	105.63	21.63	853	2797	5	15
649461	T721	41.28	1.63	40.97	1.613	117.58	24.08	893	2929	6	19
647921	T751	41.28	1.63	41.61	1.638	119.41	24.46	922	3023	8	25

**Table 11 APM2 0.50-cal., 0° obliquity V<sub>50</sub> ballistic limits for AA7056-T751 and AA7056-T721**

Plate ID	Plate temper	Nominal thickness		Actual thickness		Areal density		V <sub>50</sub>		Standard deviation	
		(mm)	(inches)	(mm)	(inches)	(kg/m <sup>2</sup> )	(lb/ft <sup>2</sup> )	(m/s)	(ft/s)	(m/s)	(ft/s)
649461	T721	38.10	1.50	36.70	1.445	105.34	21.57	625	2050	8	24
647921	T751	38.10	1.50	36.80	1.449	105.63	21.63	636	2086	8	26
649461	T721	38.10	1.50	40.97	1.613	117.58	24.08	660	2167	7	22
647921	T751	38.10	1.50	41.61	1.638	119.41	24.46	676	2218	9	30
900306	T721	50.80	2.00	50.22	1.977	144.12	29.52	754	2473	8	25
933181	T751	63.50	2.50	62.05	2.443	178.09	36.48	851	2792	7	22
933181	T751	63.50	2.50	63.37	2.495	181.88	37.25	867	2845	9	29
936221	T721	63.50	2.50	65.25	2.569	187.27	38.36	879	2882	9	29
936231	T721	63.50	2.50	65.33	2.572	187.49	38.40	856	2809	10	32
933171	T751	76.20	3.00	74.68	2.940	214.32	43.90	945	3102	6	20
933171	T751	76.20	3.00	76.35	3.006	219.13	44.88	951	3121	4	12

**Table 12** 14.5-mm BS41, 0° obliquity V<sub>50</sub> ballistic limits for AA7056-T751 and AA7056-T721

Plate ID	Plate temper	Nominal thickness		Actual thickness		Areal density		V <sub>50</sub>		Standard deviation	
		(mm)	(inches)	(mm)	(inches)	(kg/m <sup>2</sup> )	(lb/ft <sup>2</sup> )	(m/s)	(ft/s)	(m/s)	(ft/s)
933181	T751	63.50	2.50	62.05	2.443	178.09	36.48	800	2624	6	21
933181	T751	63.50	2.50	63.37	2.495	181.88	37.25	819	2686	7	21
936221	T721	63.50	2.50	65.25	2.569	187.27	38.36	809	2652	3	11
936231	T721	63.50	2.50	65.33	2.572	187.49	38.40	817	2680	6	19
933171	T751	76.20	3.00	74.68	2.940	214.32	43.90	873	2866	8	25
933171	T751	76.20	3.00	76.35	3.006	219.13	44.88	894	2932	6	20

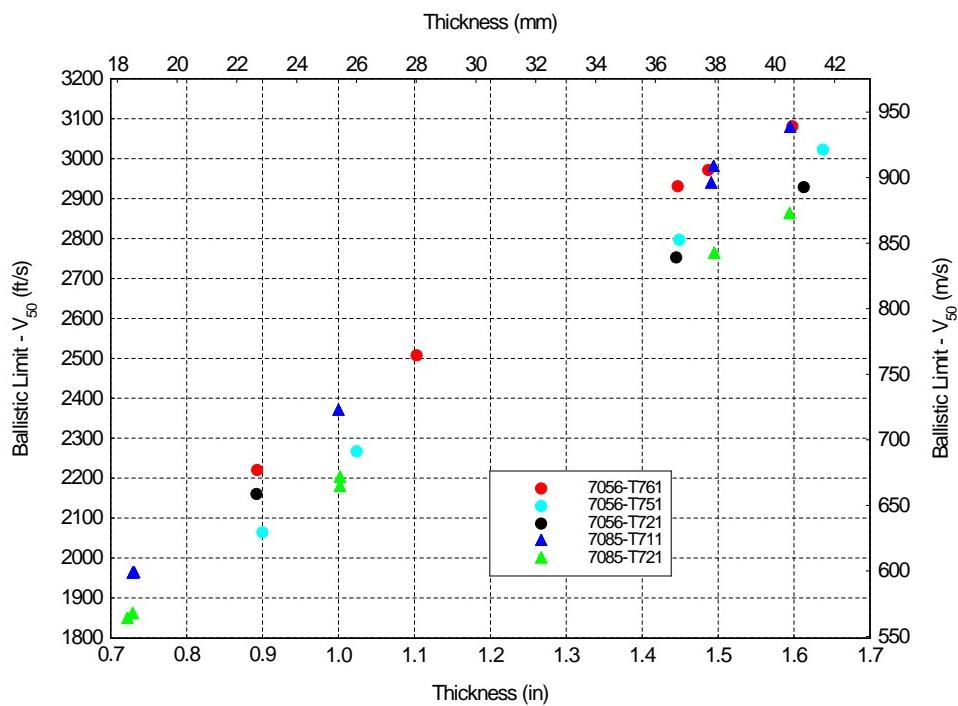
**Table 13** FSP 0.50-cal., 0° obliquity V<sub>50</sub> ballistic limits for AA7056-T751 and AA7056-T721

Plate ID	Plate temper	Nominal thickness		Actual thickness		Areal density		V <sub>50</sub>		Standard deviation	
		(mm)	(inches)	(mm)	(inches)	(kg/m <sup>2</sup> )	(lb/ft <sup>2</sup> )	(m/s)	(ft/s)	(m/s)	(ft/s)
649471	T721	22.23	0.88	22.71	0.894	65.17	13.35	957	3140	5	18
647911	T751	22.23	0.88	22.86	0.900	65.61	13.44	799	2623	18	60
647911	T751	25.40	1.00	26.01	1.024	74.65	15.29	1100	3607	5	18

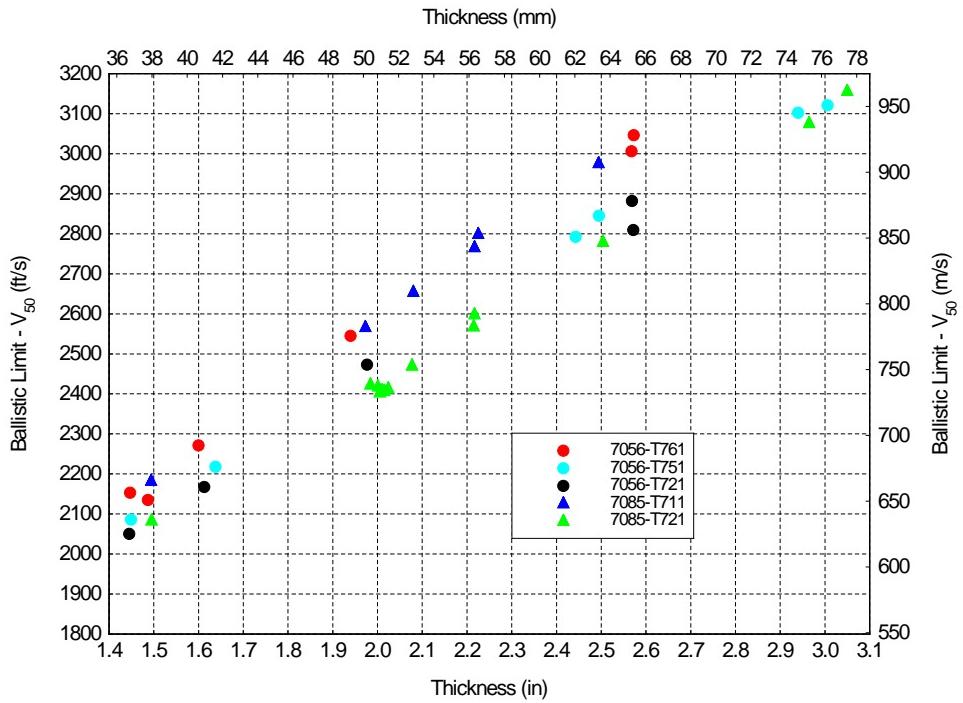
**Table 14 FSP 20-mm, 0° obliquity V<sub>50</sub> ballistic limits for AA7056-T751 and AA7056-T721**

Plate ID	Plate temper	Nominal thickness		Actual thickness		Areal density		V <sub>50</sub>		Standard deviation	
		(mm)	(inches)	(mm)	(inches)	(kg/m <sup>2</sup> )	(lb/ft <sup>2</sup> )	(m/s)	(ft/s)	(m/s)	(ft/s)
649471	T721	22.23	0.88	22.66	0.892	65.03	13.32	405	1329	7	23
647911	T751	22.23	0.88	22.86	0.900	65.61	13.44	394	1294	8	25
647911	T751	25.40	1.00	26.01	1.024	74.65	15.29	456	1495	6	21
649461	T721	38.10	1.50	36.70	1.445	105.34	21.57	874	2868	7	22
647921	T751	38.10	1.50	36.80	1.449	105.63	21.63	756	2479	11	35
649461	T721	41.28	1.63	40.97	1.613	117.58	24.08	1029	3376	8	27
647921	T751	41.28	1.63	41.61	1.638	119.41	24.46	1012	3319	2	8

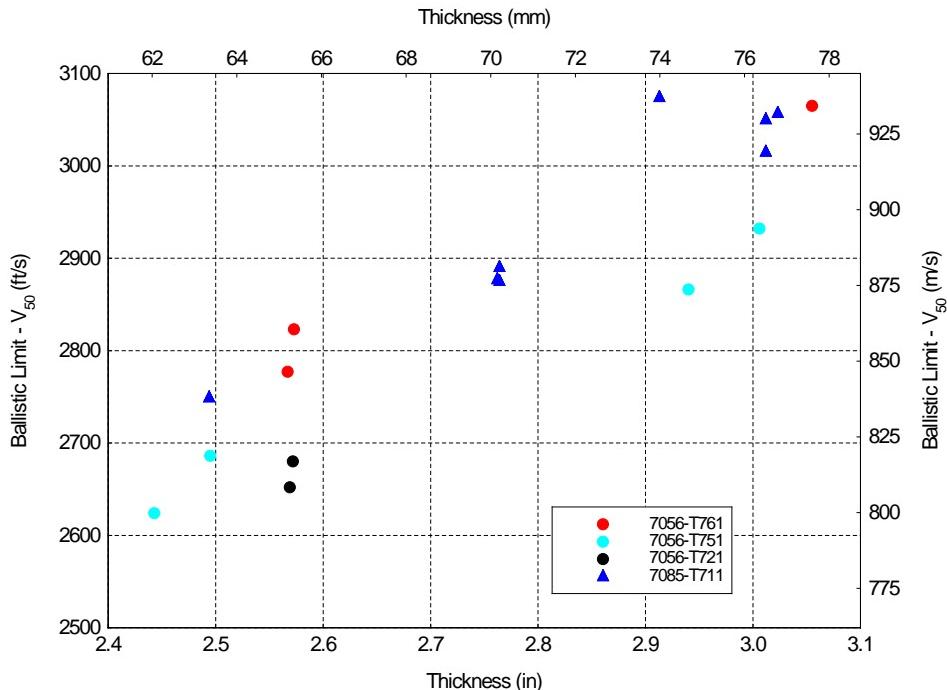
The results of the ballistic evaluation are compared directly against the ballistic performance of AA7085. Figures 4–8 show the AA7056 ballistic data collected by ARL compared with previous AA7085 data.<sup>7</sup> The data displayed are the V<sub>50</sub>'s as a function of the plate thickness. Figures 9–13 show the AA7056 ballistic data as compared with the updated 7056/7085 specification MIL-DTL-32375A.<sup>1</sup> In instances where the acceptance curve has changed from the original document (MIL-DTL-32375), the original acceptance curve is shown for reference. Note that the plates are compared on a thickness basis to be consistent with the specifications; however, the densities of the alloys vary slightly. AA7056 has a density of 2.87 g/cm<sup>3</sup>, whereas AA7085 has a density of 2.85 g/cm<sup>3</sup>.



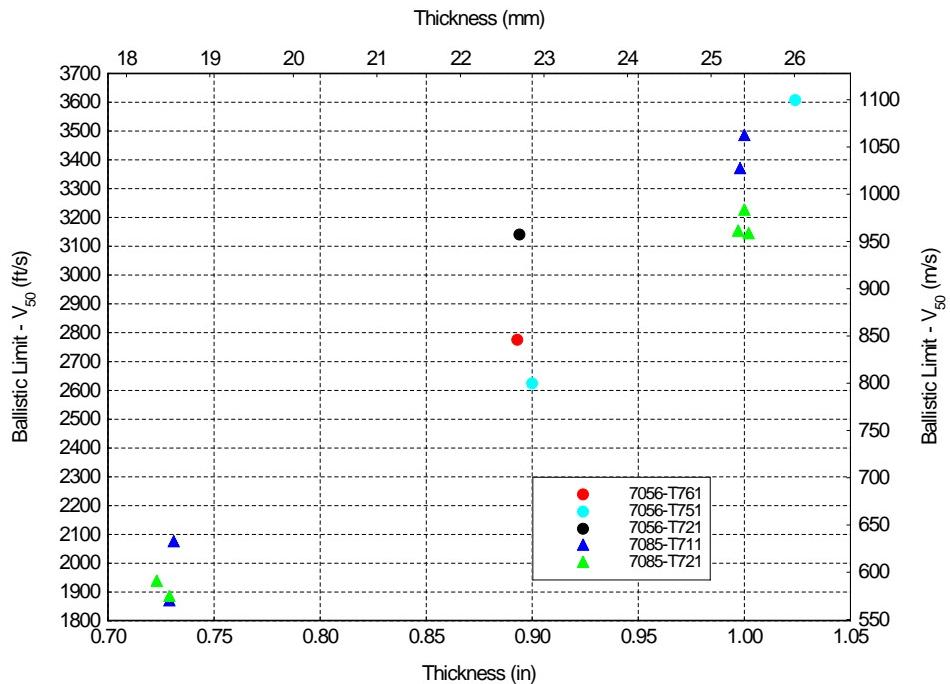
**Fig. 4** Ballistic limit vs. thickness of AA7056 and AA7085 for the 0.30-cal. APM2 at 0° obliquity



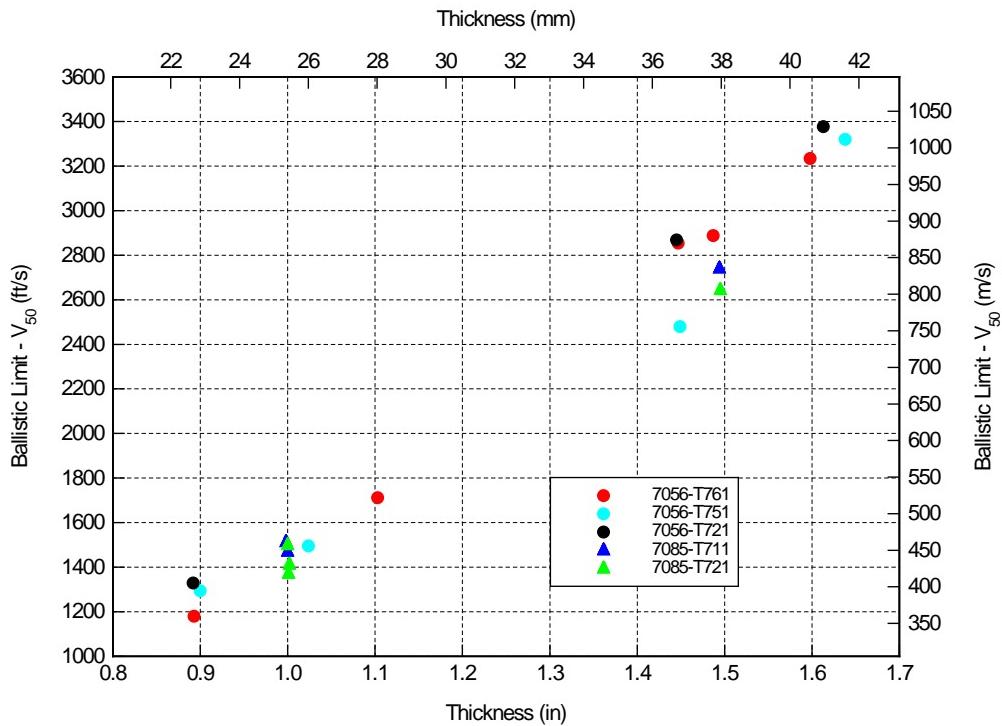
**Fig. 5** Ballistic limit vs. thickness of AA7056 and AA7085 for the 0.50-cal. APM2 at 0° obliquity



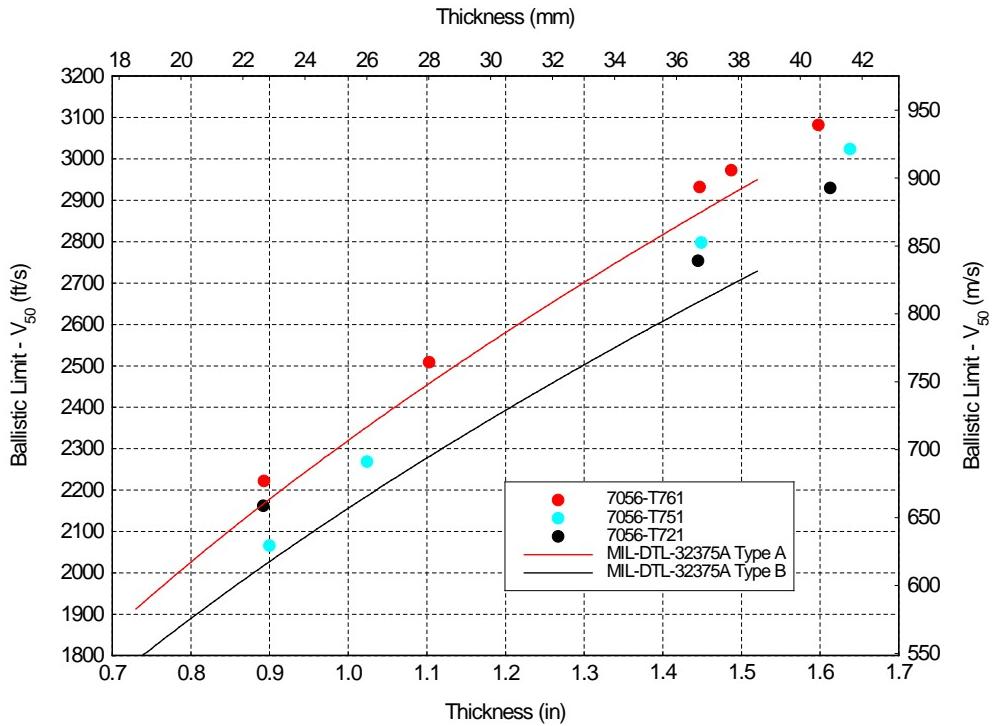
**Fig. 6** Ballistic limit vs. thickness of AA7056 and AA7085 for the 14.5-mm BS41 at 0° obliquity



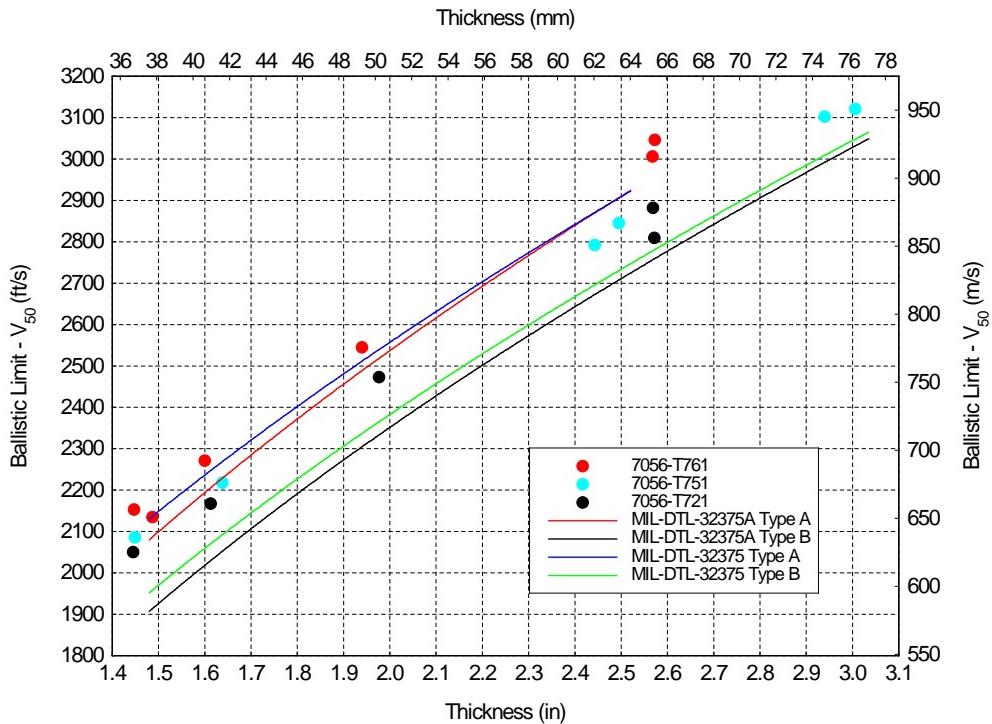
**Fig. 7** Ballistic limit vs. thickness of AA7056 and AA7085 for the 0.50-cal. FSP at 0° obliquity



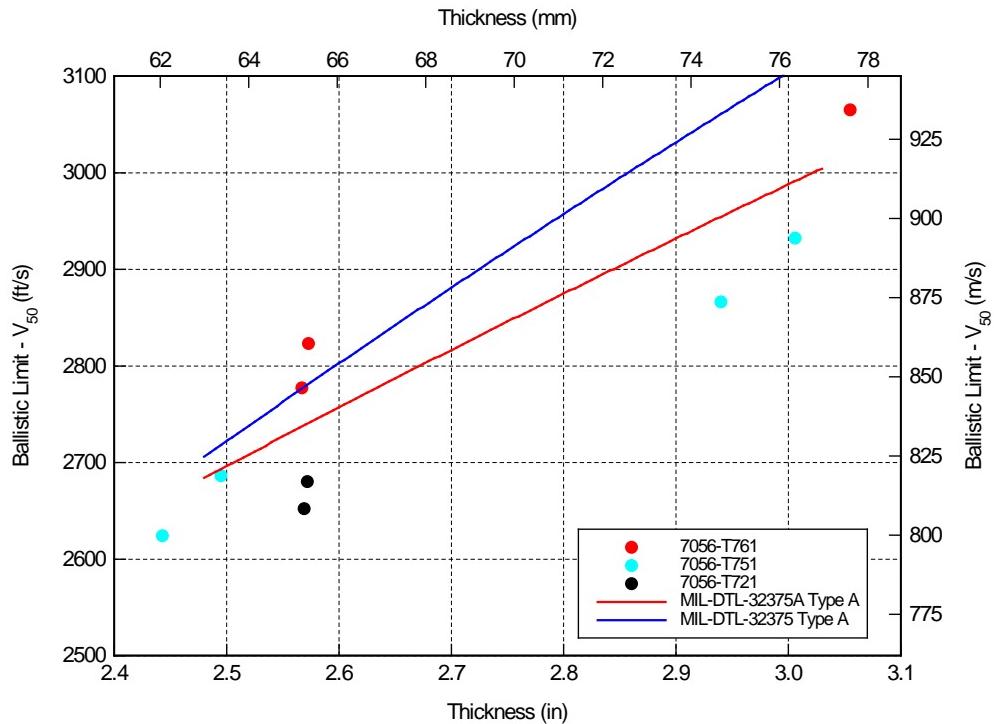
**Fig. 8** Ballistic limit vs. thickness of AA7056 and AA7085 for the 20-mm FSP at 0° obliquity



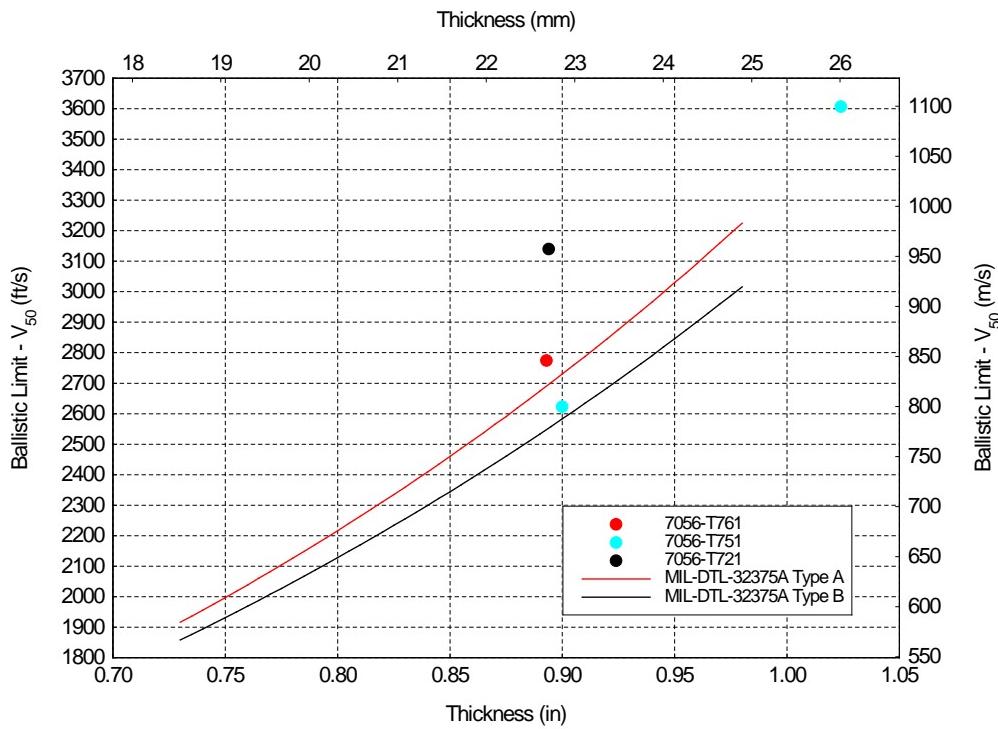
**Fig. 9** Ballistic limit vs. thickness of AA7056 as compared with MIL-DTL-32375A for the 0.30-cal. APM2 at 0° obliquity



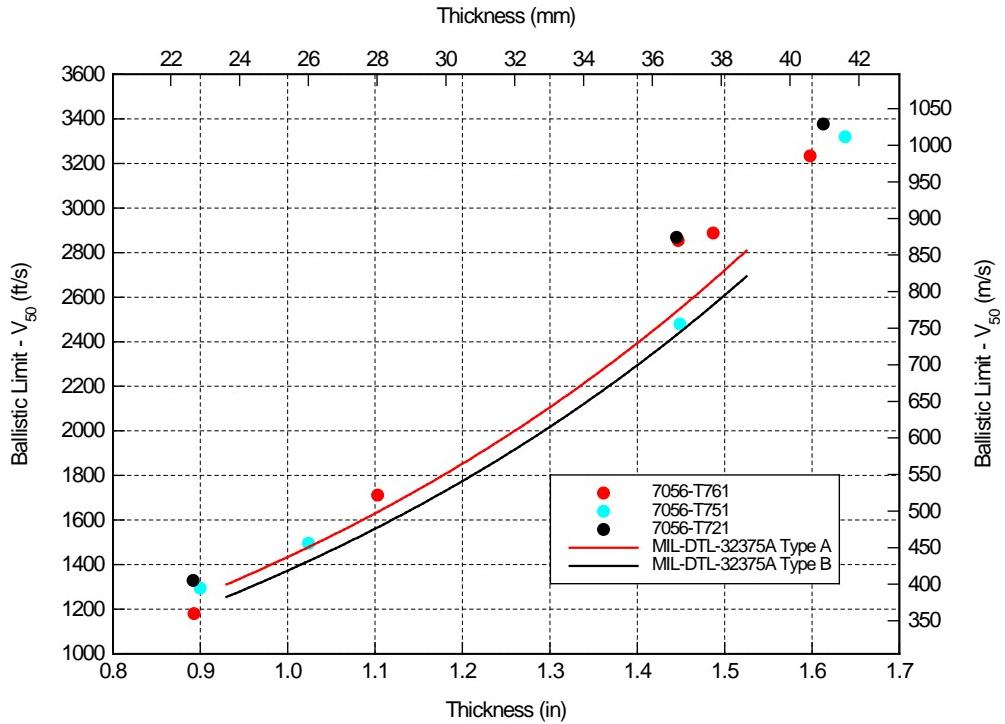
**Fig. 10** Ballistic limit vs. thickness of AA7056 as compared with MIL-DTL-32375 and the revised MIL-DTL-32375A for the 0.50-cal. APM2 at 0° obliquity



**Fig. 11** Ballistic limit vs. thickness of AA7056 as compared with MIL-DTL-32375 and the revised MIL-DTL-32375A for the 14.5-mm BS41 at 0° obliquity



**Fig. 12** Ballistic limit vs. thickness of AA7056 as compared with MIL-DTL-32375A for the 0.50-cal. FSP at 0° obliquity



**Fig. 13 Ballistic limit vs. thickness of AA7056 as compared with MIL-DTL-32375A for the 20-mm FSP at 0° obliquity**

As can be observed in Figs. 4–8, the performance for AA7056 is similar to the existing AA7085 material. It would not be a stretch to consider them one data set to develop an acceptance curve. Therefore, it was decided to use one set of acceptance curves for both materials rather than include individual curves for each material in the specification. For the 0.30-cal. APM2, 0.50-cal. FSP, and 20-mm FSP (Figs. 9, 12, and 13), no changes were made to the original acceptance curves. Using the data presented in this report and additional data that had been generated on AA7085 after the original specification publication, the acceptance curves were adjusted for plate thickness requiring acceptance with the 0.50-cal. APM2 and 14.5-mm BS41 (Figs. 10 and 11). The 0.50-cal. APM2 curves were adjusted because the original curves were too close to the actual  $V_{50}$  performance of the plates in those thickness ranges and a high number of material lots were failing acceptance testing. The 14.5-mm BS41 was adjusted because the original curve was based on a limited number of experiments, and an unusually high  $V_{50}$  data point for a nominally 76.2-mm plate caused the curve to significantly shift upward. Now, with more data available, a more appropriate acceptance curve has been derived. The new acceptance velocities were calculated by fitting the combined 7056 and 7085  $V_{50}$  data minus 2 standard deviations with Eqs. 3 and 4 for AP and FSP projectiles, respectively.<sup>8,9</sup>

$$V_A = 1000\sqrt{a+bt} . \quad (3)$$

$$V_A = 1000e^{a+bt} . \quad (4)$$

In Eqs. 3 and 4,  $V_A$  is the acceptance velocity,  $t$  is the actual thickness of the plate, and both  $a$  and  $b$  are constants of regression. Table 15 lists the constants of regression for each projectile. The ballistic tables corresponding to the acceptance curves can be found in MIL-DTL-32375A (MR).

**Table 15 Constants of regression for the acceptance curves for AA7056 and AA7085 used in MIL-DTL-32375A**

Projectile type	7056-T761/7085-T711		7056-T721/7056-T751/7085-T721	
	a	b	a	b
0.30-cal. APM2 at 0°	-1.00510	6.38362	-0.73629	5.38098
0.50-cal. APM2 at 0°	-1.68208	4.05994	-1.74964	3.63981
14.5-mm BS41 at 0°	-1.01917	3.31534	...	...
0.50-cal. FSP at 0°	-0.87107	2.08372	-0.79585	1.93870
20-mm FSP at 0°	-0.92069	1.28106	-0.96678	1.28373

## 5. Conclusions

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A ballistic evaluation has been performed on AA7056 in the T761, T751, and T721 tempers. This report has compared the performance of AA7056 against existing mil-spec Al-armor material, namely AA7085. AA7056 performed similar to AA7085 against the mil-spec projectiles at equal thicknesses. This report has also documented the calculations used to derive the acceptance tables included in the updated MIL-DTL-32375A (MR).

## **6. References**

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1. MIL-DTL-32375A (MR). Armor plate, aluminum, alloy, 7056 and 7085 unweldable appliqué. Aberdeen Proving Ground (MD): Army Research Laboratory (US); 2016 Jan 21.
2. International alloy designations and chemical composition limits for wrought aluminum and wrought aluminum alloys. Arlington (VA): The Aluminum Association, Inc.; 2015 Jan.
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6. MIL-DTL-46593B (MR). Projectile, calibers .22, .30, .50, and 20 mm fragment-simulating. Aberdeen Proving Ground (MD): Army Research Laboratory (US); 2008 Aug 11.
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8. DeLuca E, Anctil A. Laminate armor for light combat vehicles. Watertown (MA): Army Materials Technology Laboratory (US); 1986 Apr. Report No.: MTL TR 86-14.
9. Van Caneghem R, Typanski D, Latham R. Appendix C: ballistic testing of aluminum armor alloys – shock testing of weldments and specification data. Aberdeen Proving Ground (MD): Army Combat Systems Test Activity (US); 1986 Apr. Report No.: MTL TR 86-14.

## **Appendix A. Ballistic Data: 7056-T761**

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This appendix appears in its original form, without editorial change.

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## 0.30-cal APM2

Target:	<b>7056-T761</b>			Date:	<b>4/21/2015</b>	
Plate Number:	<b>823551</b>			Location:	<b>EF 106</b>	
Thickness, in:	<b>0.893</b>					
Thickness, mm:	<b>22.68</b>					
Hardness, BHN:	<b>179</b>					
Obliquity:	<b>0°</b>					
Projectile:	<b>0.30-cal APM2</b>					
Velocity Measurement:	<b>Chronograph</b>					
V <sub>50</sub> :	<b>2221 ft/s</b>	<b>677 m/s</b>	Number of Shots:		<b>4</b>	
Std Dev:	<b>23 ft/s</b>	<b>7 m/s</b>	Spread:		<b>54 ft/s</b>	<b>16 m/s</b>
ZMR:	<b>36 ft/s</b>	<b>11 m/s</b>				
Striking Velocity (ft/s)	Gamma (m/s)	Result (deg)	Used for V <sub>50</sub> (Yes/No)	Shot Number	Comments	
2127	648	--	PP	No		
2403	732	--	CP	No	14299	
<b>2249</b>	<b>685</b>	<b>--</b>	<b>PP</b>	<b>Yes</b>	<b>14300</b>	
2335	712	--	CP	No	14301	
2400	731	--	CP	No	14302	
2264	690	--	CP	No	14303	
<b>2227</b>	<b>679</b>	<b>--</b>	<b>CP</b>	<b>Yes</b>	<b>14304</b>	
<b>2195</b>	<b>669</b>	<b>--</b>	<b>PP</b>	<b>Yes</b>	<b>14305</b>	
2145	654	--	PP	No	14306	
<b>2213</b>	<b>674</b>	<b>--</b>	<b>CP</b>	<b>Yes</b>	<b>14307</b>	

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Target:	<b>7056-T761</b>			Date:	<b>4/14/2015</b>	
Plate Number:	<b>823531</b>			Location:	<b>EF 106</b>	
Thickness, in:	<b>1.598</b>					
Thickness, mm:	<b>40.59</b>					
Hardness, BHN:	<b>170</b>					
Oblliquity:	<b>0°</b>					
Projectile:	<b>0.30-cal APM2</b>					
Velocity Measurement:	<b>Chronograph</b>					
V <sub>50</sub> :	<b>3081 ft/s</b>	<b>939 m/s</b>		Number of Shots:	<b>4</b>	
Std Dev:	<b>22 ft/s</b>	<b>6 m/s</b>		Spread:	<b>48 ft/s</b>	<b>14 m/s</b>
ZMR:	<b>N/A</b>	<b>N/A</b>				
Striking Velocity (ft/s)	Gamma (m/s)	Result (deg)		Used for V <sub>50</sub> (Yes/No)	Shot Number	Comments
2920	890	--	PP	No	14285	
<b>3112</b>	<b>948</b>	--	<b>CP</b>	<b>Yes</b>	<b>14286</b>	
3020	920	--	PP	No	14287	
<b>3064</b>	<b>934</b>	--	<b>PP</b>	<b>Yes</b>	<b>14288</b>	
<b>3078</b>	<b>938</b>	--	<b>CP</b>	<b>Yes</b>	<b>14289</b>	
<b>3069</b>	<b>935</b>	--	<b>PP</b>	<b>Yes</b>	<b>14290</b>	

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Target:	<b>7056-T761</b>			Date:	<b>1/22/2015</b>	
Plate Number:	<b>823551</b>			Location:	<b>EF 106</b>	
Thickness, in:	<b>1.103</b>					
Thickness, mm:	<b>28.02</b>					
Hardness, BHN:	<b>179</b>					
Oblliquity:	<b>0°</b>					
Projectile:	<b>0.30-cal APM2</b>					
Velocity Measurement:	<b>Chronograph</b>					
V <sub>50</sub> :	<b>2508 ft/s</b>	<b>764 m/s</b>	Number of Shots:		<b>4</b>	
Std Dev:	<b>22 ft/s</b>	<b>7 m/s</b>	Spread:		<b>50 ft/s</b>	<b>15 m/s</b>
ZMR:	<b>N/A</b>	<b>N/A</b>				
Striking Velocity (ft/s)	Gamma (m/s)	Result (deg)	Used for V <sub>50</sub> (Yes/No)	Shot Number	Comments	
2547	776	--	CP	No		
2416	736	--	PP	No	14147	
<b>2507</b>	<b>764</b>	<b>--</b>	<b>PP</b>	<b>Yes</b>	<b>14148</b>	
2552	778	--	CP	No	14149	
2447	746	--	PP	No	14150	
2538	774	--	CP	No	14151	
2544	775	--	CP	No	14152	
<b>2477</b>	<b>755</b>	<b>--</b>	<b>PP</b>	<b>Yes</b>	<b>14153</b>	
<b>2527</b>	<b>770</b>	<b>--</b>	<b>CP</b>	<b>Yes</b>	<b>14154</b>	
<b>2520</b>	<b>768</b>	<b>--</b>	<b>CP</b>	<b>Yes</b>	<b>14155</b>	

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Target:	<b>7056-T761</b>			Date:	<b>1/20/2015</b>	
Plate Number:	<b>823531</b>			Location:	<b>EF 106</b>	
Thickness, in:	<b>1.447</b>					
Thickness, mm:	<b>36.75</b>					
Hardness, BHN:	<b>174</b>					
Oblliquity:	<b>0°</b>					
Projectile:	<b>0.30-cal APM2</b>					
Velocity Measurement:	<b>Chronograph</b>					
V <sub>50</sub> :	<b>2931 ft/s</b>	<b>893 m/s</b>	Number of Shots:		<b>4</b>	
Std Dev:	<b>26 ft/s</b>	<b>8 m/s</b>	Spread:		<b>53 ft/s</b>	<b>16 m/s</b>
ZMR:	<b>N/A</b>	<b>N/A</b>				
Striking Velocity (ft/s)	Gamma (m/s)	Result (deg)	Used for V <sub>50</sub> (Yes/No)	Shot Number	Comments	
<b>2953</b>	<b>900</b>	--	<b>CP</b>	<b>Yes</b>		
2756	840	--	PP	No	14136	
2852	869	--	PP	No	14137	
<b>2900</b>	<b>884</b>	--	<b>PP</b>	<b>Yes</b>	<b>14138</b>	
<b>2919</b>	<b>890</b>	--	<b>PP</b>	<b>Yes</b>	<b>14139</b>	
<b>2951</b>	<b>899</b>	--	<b>CP</b>	<b>Yes</b>	<b>14140</b>	

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## 0.50-cal APM2

Target:	<b>7056-T761</b>			Date:	<b>3/26/2015</b>	
Plate Number:	<b>823531</b>			Location:	<b>EF 108</b>	
Thickness, in:	<b>1.447</b>					
Thickness, mm:	<b>36.75</b>					
Hardness, BHN:	<b>174</b>					
Obliquity:	<b>0°</b>					
Projectile:	<b>0.50 cal APM2</b>					
Velocity Measurement:	<b>X-Ray</b>					
V <sub>50</sub> :	<b>2153 ft/s</b>	<b>656 m/s</b>		Number of Shots:	<b>4</b>	
Std Dev:	<b>25 ft/s</b>	<b>8 m/s</b>		Spread:	<b>56 ft/s</b>	<b>17 m/s</b>
ZMR:	<b>N/A</b>	<b>N/A</b>				
Striking Velocity (ft/s)	Gamma (m/s)	Result (deg)	Used for V <sub>50</sub> (Yes/No)	Shot Number	Comments	
2284	696	0.22	CP	No	12608	
2206	672	0.88	CP	No	12609	
2080	634	0.40	PP	No	12610	
<b>2182</b>	<b>665</b>	<b>0.54</b>	<b>CP</b>	<b>Yes</b>	<b>12611</b>	
<b>2126</b>	<b>648</b>	<b>0.14</b>	<b>PP</b>	<b>Yes</b>	<b>12612</b>	
<b>2139</b>	<b>652</b>	<b>0.61</b>	<b>PP</b>	<b>Yes</b>	<b>12613</b>	
<b>2165</b>	<b>660</b>	<b>0.52</b>	<b>CP</b>	<b>Yes</b>	<b>12614</b>	

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Target:	<b>7056-T761</b>			Date:	<b>2/13/2015</b>	
Plate Number:	<b>823561</b>			Location:	<b>EF 108</b>	
Thickness, in:	<b>2.573</b>					
Thickness, mm:	<b>65.35</b>					
Hardness, BHN:	<b>179</b>					
Oblliquity:	<b>0°</b>					
Projectile:	<b>0.50 cal APM2</b>					
Velocity Measurement:	<b>X-Ray</b>					
V <sub>50</sub> :	<b>3046 ft/s</b>	<b>928 m/s</b>		Number of Shots:	<b>4</b>	
Std Dev:	<b>20 ft/s</b>	<b>6 m/s</b>		Spread:	<b>48 ft/s</b>	<b>14 m/s</b>
ZMR:	<b>N/A</b>	<b>N/A</b>				
Striking Velocity (ft/s)	Gamma (m/s)	Result (deg)		Used for V <sub>50</sub> (Yes/No)	Shot Number	Comments
3164	964	1.14	CP	No	12541	
<b>3024</b>	<b>922</b>	<b>0.82</b>	<b>PP</b>	<b>Yes</b>	<b>12542</b>	
3112	948	0.47	CP	No	12543	
3110	948	1.21	CP	No	12544	
<b>3072</b>	<b>936</b>	<b>0.62</b>	<b>CP</b>	<b>Yes</b>	<b>12545</b>	
<b>3046</b>	<b>928</b>	<b>0.47</b>	<b>PP</b>	<b>Yes</b>	<b>12546</b>	
<b>3043</b>	<b>927</b>	<b>0.26</b>	<b>CP</b>	<b>Yes</b>	<b>12547</b>	

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Target:	<b>7056-T761</b>			Date:	<b>2/10/2015</b>	
Plate Number:	<b>823531</b>			Location:	<b>EF 108</b>	
Thickness, in:	<b>1.600</b>					
Thickness, mm:	<b>40.64</b>					
Hardness, BHN:	<b>170</b>					
Oblliquity:	<b>0°</b>					
Projectile:	<b>0.50 cal APM2</b>					
Velocity Measurement:	<b>X-Ray</b>					
V <sub>50</sub> :	<b>2271 ft/s</b>	<b>692 m/s</b>	Number of Shots:		<b>4</b>	
Std Dev:	<b>20 ft/s</b>	<b>6 m/s</b>	Spread:		<b>46 ft/s</b>	<b>14 m/s</b>
ZMR:	<b>N/A</b>	<b>N/A</b>				
Striking Velocity (ft/s)	Gamma (m/s)	Result (deg)	Used for V <sub>50</sub> (Yes/No)	Shot Number	Comments	
2535	773	0.89	CP	No		
2336	712	0.42	CP	No	12529	
2191	668	0.45	PP	No	12530	
<b>2259</b>	<b>689</b>	<b>0.23</b>	<b>PP</b>	<b>Yes</b>	<b>12531</b>	
2329	710	0.28	CP	No	12532	
<b>2298</b>	<b>700</b>	<b>1.01</b>	<b>CP</b>	<b>Yes</b>	<b>12533</b>	
<b>2252</b>	<b>686</b>	<b>0.18</b>	<b>PP</b>	<b>Yes</b>	<b>12534</b>	
<b>2273</b>	<b>693</b>	<b>0.91</b>	<b>CP</b>	<b>Yes</b>	<b>12535</b>	

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Target:	<b>7056-T761</b>			Date:	<b>8/27/2015</b>	
Plate Number:	<b>900294</b>			Location:	<b>EF 108</b>	
Thickness, in:	<b>1.940</b>					
Thickness, mm:	<b>49.28</b>					
Hardness, BHN:	<b>170</b>					
Oblliquity:	<b>0°</b>					
Projectile:	<b>0.50 cal APM2</b>					
Velocity Measurement:	<b>X-Ray</b>					
V <sub>50</sub> :	<b>2545 ft/s</b>	<b>776 m/s</b>	Number of Shots:		<b>4</b>	
Std Dev:	<b>17 ft/s</b>	<b>5 m/s</b>	Spread:		<b>41 ft/s</b>	<b>12 m/s</b>
ZMR:	<b>N/A</b>	<b>N/A</b>				
Striking Velocity (ft/s)	Gamma (m/s)	Result (deg)	Used for V <sub>50</sub> (Yes/No)	Shot Number	Comments	
2671	814	0.65	CP	No		
2621	799	0.54	CP	No	12944	
2620	799	0.45	CP	No	12945	
2457	749	0.20	PP	No	12946	
<b>2526</b>	<b>770</b>	<b>0.36</b>	<b>PP</b>	<b>Yes</b>	<b>12947</b>	
<b>2567</b>	<b>782</b>	<b>0.73</b>	<b>CP</b>	<b>Yes</b>	<b>12948</b>	
<b>2539</b>	<b>774</b>	<b>0.68</b>	<b>PP</b>	<b>Yes</b>	<b>12949</b>	
<b>2546</b>	<b>776</b>	<b>0.30</b>	<b>CP</b>	<b>Yes</b>	<b>12950</b>	

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## 14.5-mm BS41

Target:	<b>7056-T761</b>			Date:	<b>2/26/2015</b>	
Plate Number:	<b>823561</b>			Location:	<b>EF 106</b>	
Thickness, in:	<b>2.573</b>					
Thickness, mm:	<b>65.35</b>					
Hardness, BHN:	<b>179</b>					
Obliquity:	<b>0°</b>					
Projectile:	<b>14.5-mm BS41</b>					
Velocity Measurement:	<b>X-Ray</b>					
V <sub>50</sub> :	<b>2823 ft/s</b>	<b>860 m/s</b>	Number of Shots:		<b>4</b>	
Std Dev:	<b>17 ft/s</b>	<b>5 m/s</b>	Spread:		<b>42 ft/s</b>	<b>13 m/s</b>
ZMR:	<b>5 ft/s</b>	<b>2 m/s</b>				
Striking Velocity	Gamma	Result (PP/CP)	Used for V <sub>50</sub> (Yes/No)	Shot Number	Comments	
(ft/s)	(m/s)					
<b>2825</b>	<b>861</b>	<b>1.02</b>	<b>PP</b>	<b>Yes</b>	<b>14204</b>	
2962	903	1.54	CP	No	14205	
2945	898	1.19	CP	No	14206	
2913	888	0.96	CP	No	14207	
2923	891	--	CP	No	14208	Swithched to Chrono
2887	880	--	CP	No	14209	
<b>2844</b>	<b>867</b>	--	<b>CP</b>	<b>Yes</b>	<b>14210</b>	
<b>2820</b>	<b>859</b>	--	<b>CP</b>	<b>Yes</b>	<b>14211</b>	
<b>2802</b>	<b>854</b>	--	<b>PP</b>	<b>Yes</b>	<b>14212</b>	
2790	850	--	PP	No	14213	

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Target:	<b>7056-T761</b>			Date:	<b>8/31/2015</b>	
Plate Number:	<b>900293</b>			Location:	<b>EF 108</b>	
Thickness, in:	<b>3.055</b>					
Thickness, mm:	<b>77.60</b>					
Hardness, BHN:	<b>183</b>					
Oblliquity:	<b>0°</b>					
Projectile:	<b>14.5-mm BS41</b>					
Velocity Measurement:	<b>X-ray</b>					
V <sub>50</sub> :	<b>3065 ft/s</b>	<b>934 m/s</b>		Number of Shots:	<b>4</b>	
Std Dev:	<b>26 ft/s</b>	<b>8 m/s</b>		Spread:	<b>59 ft/s</b>	<b>18 m/s</b>
ZMR:	<b>N/A</b>	<b>N/A</b>				
Striking Velocity (ft/s)	Gamma (m/s)	Result (deg)		Used for V <sub>50</sub> (Yes/No)	Shot Number	Comments
3210	978	0.10	CP	No	12951	
3175	968	0.37	CP	No	12952	
<b>3099</b>	<b>945</b>	<b>0.59</b>	<b>CP</b>	<b>Yes</b>	<b>12953</b>	
3030	923	0.30	PP	No	12954	
<b>3040</b>	<b>927</b>	<b>0.36</b>	<b>PP</b>	<b>Yes</b>	<b>12955</b>	
<b>3068</b>	<b>935</b>	<b>0.58</b>	<b>CP</b>	<b>Yes</b>	<b>12956</b>	
<b>3051</b>	<b>930</b>	<b>0.20</b>	<b>PP</b>	<b>Yes</b>	<b>12957</b>	

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## 0.50-cal FSP

Target:	<b>7056-T761</b>			Date:	<b>1/29/2015</b>	
Plate Number:	<b>823551</b>			Location:	<b>EF 106</b>	
Thickness, in:	<b>0.893</b>					
Thickness, mm:	<b>22.68</b>					
Hardness, BHN:	<b>179</b>					
Obliquity:	<b>0°</b>					
Projectile:	<b>0.50-cal FSP</b>					
Velocity Measurement:	<b>Chronograph</b>					
V <sub>50</sub> :	<b>2774 ft/s</b>	<b>846 m/s</b>	Number of Shots:		<b>4</b>	
Std Dev:	<b>19 ft/s</b>	<b>5 m/s</b>	Spread:		<b>45 ft/s</b>	<b>13 m/s</b>
ZMR:	<b>3 ft/s</b>	<b>1 m/s</b>				
Striking Velocity	Gamma	Result (PP/CP)	Used for V <sub>50</sub> (Yes/No)	Shot Number	Comments	
(ft/s)	(m/s)					
2972	906	--	CP	No	14156	
2719	829	--	PP	No	14157	
2836	864	--	CP	No	14158	
<b>2776</b>	<b>846</b>	--	<b>CP</b>	<b>Yes</b>	<b>14159</b>	
<b>2748</b>	<b>838</b>	--	<b>PP</b>	<b>Yes</b>	<b>14160</b>	
<b>2793</b>	<b>851</b>	--	<b>CP</b>	<b>Yes</b>	<b>14161</b>	
<b>2779</b>	<b>847</b>	--	<b>PP</b>	<b>Yes</b>	<b>14162</b>	

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## 20-mm FSP

Target:	<b>7056-T761</b>			Date:	<b>4/1/2015</b>	
Plate Number:	<b>823551</b>			Location:	<b>EF 106</b>	
Thickness, in:	<b>0.893</b>					
Thickness, mm:	<b>22.68</b>					
Hardness, BHN:	<b>179</b>					
Obliquity:	<b>0°</b>					
Projectile:	<b>20-mm FSP</b>					
Velocity Measurement:	<b>X-ray</b>					
V <sub>50</sub> :	<b>1180 ft/s</b>	<b>360 m/s</b>	Number of Shots:		<b>10</b>	
Std Dev:	<b>45 ft/s</b>	<b>14 m/s</b>	Spread:		<b>126 ft/s</b>	<b>38 m/s</b>
ZMR:	<b>110 ft/s</b>	<b>33 m/s</b>				
Striking Velocity (ft/s)	Gamma (m/s)	Result (PP/CP) (deg)	Used for V <sub>50</sub> (Yes/No)	Shot Number	Comments	
1364	416	0.23	CP	No	14260	
<b>1261</b>	<b>384</b>	<b>1.95</b>	<b>PP</b>	<b>Yes</b>	<b>14261</b>	
1305	398	1.01	CP	No	14262	
<b>1236</b>	<b>377</b>	<b>1.44</b>	<b>CP</b>	<b>Yes</b>	<b>14263</b>	
<b>1220</b>	<b>372</b>	<b>0.55</b>	<b>CP</b>	<b>Yes</b>	<b>14264</b>	
<b>1146</b>	<b>349</b>	<b>0.10</b>	<b>PP</b>	<b>Yes</b>	<b>14265</b>	
<b>1197</b>	<b>365</b>	<b>0.62</b>	<b>CP</b>	<b>Yes</b>	<b>14266</b>	
<b>1168</b>	<b>356</b>	<b>0.75</b>	<b>CP</b>	<b>Yes</b>	<b>14267</b>	
<b>1135</b>	<b>346</b>	<b>1.12</b>	<b>PP</b>	<b>Yes</b>	<b>14268</b>	
<b>1151</b>	<b>351</b>	<b>0.68</b>	<b>CP</b>	<b>Yes</b>	<b>14269</b>	
<b>1138</b>	<b>347</b>	<b>0.72</b>	<b>PP</b>	<b>Yes</b>	<b>14270</b>	
<b>1149</b>	<b>350</b>	<b>0.83</b>	<b>PP</b>	<b>Yes</b>	<b>14271</b>	

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Target:	<b>7056-T761</b>			Date:	<b>4/8/2015</b>	
Plate Number:	<b>823531</b>			Location:	<b>EF 106</b>	
Thickness, in:	<b>1.598</b>					
Thickness, mm:	<b>40.59</b>					
Hardness, BHN:	<b>170</b>					
Oblliquity:	<b>0°</b>					
Projectile:	<b>20-mm FSP</b>					
Velocity Measurement:	<b>X-ray</b>					
V <sub>50</sub> :	<b>3234 ft/s</b>	<b>986 m/s</b>		Number of Shots:	<b>4</b>	
Std Dev:	<b>14 ft/s</b>	<b>4 m/s</b>		Spread:	<b>32 ft/s</b>	<b>10 m/s</b>
ZMR:	<b>12 ft/s</b>	<b>4 m/s</b>				
Striking Velocity (ft/s)	Gamma (m/s)	Result (PP/CP) (deg)	Used for V <sub>50</sub> (Yes/No)	Shot Number	Comments	
3543	1080	0.65	CP	No	14276	
3374	1028	1.97	CP	No	14277	
<b>3242</b>	<b>988</b>	<b>0.63</b>	<b>PP</b>	<b>Yes</b>	<b>14278</b>	
3299	1005	1.32	CP	No	14279	
<b>3230</b>	<b>984</b>	<b>0.43</b>	<b>CP</b>	<b>Yes</b>	<b>14280</b>	
<b>3247</b>	<b>990</b>	<b>1.30</b>	<b>CP</b>	<b>Yes</b>	<b>14281</b>	
<b>3215</b>	<b>980</b>	<b>1.34</b>	<b>PP</b>	<b>Yes</b>	<b>14282</b>	

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Target:	<b>7056-T761</b>			Date:	<b>2/10/2015</b>	
Plate Number:	<b>823551</b>			Location:	<b>EF 106</b>	
Thickness, in:	<b>1.103</b>					
Thickness, mm:	<b>28.02</b>					
Hardness, BHN:	<b>179</b>					
Oblliquity:	<b>0°</b>					
Projectile:	<b>20-mm FSP</b>					
Velocity Measurement:	<b>X-ray</b>					
V <sub>50</sub> :	<b>1711 ft/s</b>	<b>522 m/s</b>	Number of Shots:		<b>4</b>	
Std Dev:	<b>15 ft/s</b>	<b>4 m/s</b>	Spread:		<b>35 ft/s</b>	<b>10 m/s</b>
ZMR:	<b>35 ft/s</b>	<b>10 m/s</b>				
Striking Velocity (ft/s)	Gamma (m/s)	Result (PP/CP) (deg)	Used for V <sub>50</sub> (Yes/No)	Shot Number	Comments	
2707	825	0.05	CP	No	14181	
2541	774	1.10	CP	No	14182	
2271	692	1.30	CP	No	14183	
1888	575	1.22	CP	No	14184	
<b>1716</b>	<b>523</b>	<b>1.01</b>	<b>PP</b>	<b>Yes</b>	<b>14185</b>	
<b>1724</b>	<b>525</b>	<b>1.63</b>	<b>PP</b>	<b>Yes</b>	<b>14186</b>	
1804	550	0.49	CP	No	14187	
<b>1716</b>	<b>523</b>	<b>0.26</b>	<b>CP</b>	<b>Yes</b>	<b>14188</b>	
1692	516	1.01	PP	No	14189	
<b>1689</b>	<b>515</b>	<b>0.64</b>	<b>CP</b>	<b>Yes</b>	<b>14190</b>	

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## **Appendix B. Ballistic Data: 7056-T751 and 7056-T721**

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This appendix appears in its original form, without editorial change.  
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## 0.30-cal APM2

Target:	<b>7056-T751</b>			Date:	<b>8/26/2014</b>	
Plate Number:	<b>647911</b>			Location:	<b>EF 106</b>	
Thickness, in:	<b>1.024</b>					
Thickness, mm:	<b>26.01</b>					
Hardness, BHN:	<b>156</b>					
Obliquity:	<b>0°</b>					
Projectile:	<b>0.30-cal APM2</b>					
Velocity Measurement:	<b>Chronograph</b>					
V <sub>50</sub> :	<b>2268 ft/s</b>	<b>691 m/s</b>		Number of Shots:	<b>4</b>	
Std Dev:	<b>19 ft/s</b>	<b>6 m/s</b>		Spread:	<b>44 ft/s</b>	<b>13 m/s</b>
ZMR:	<b>6 ft/s</b>	<b>2 m/s</b>				
Striking Velocity (ft/s)	Gamma (m/s)	Result (PP/CP) (deg)	Used for V <sub>50</sub> (Yes/No)	Shot Number	Comments	
<b>2251</b>	<b>686</b>	--	<b>PP</b>	<b>Yes</b>	<b>13843</b>	
2381	726	--	CP	No	13844	
<b>2265</b>	<b>690</b>	--	<b>PP</b>	<b>Yes</b>	<b>13845</b>	
2385	727	--	CP	No	13846	
2335	712	--	CP	No	13847	
<b>2295</b>	<b>699</b>	--	<b>CP</b>	<b>Yes</b>	<b>13848</b>	
2325	709	--	CP	No	13849	
<b>2259</b>	<b>689</b>	--	<b>CP</b>	<b>Yes</b>	<b>13850</b>	

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Target:	<b>7056-T751</b>			Date:	<b>8/25/2014</b>	
Plate Number:	<b>647911</b>			Location:	<b>EF 106</b>	
Thickness, in:	<b>0.900</b>					
Thickness, mm:	<b>22.86</b>					
Hardness, BHN:	<b>159</b>					
Oblliquity:	<b>0°</b>					
Projectile:	<b>0.30-cal APM2</b>					
Velocity Measurement:	<b>Chronograph</b>					
V <sub>50</sub> :	<b>2065 ft/s</b>	<b>629 m/s</b>	Number of Shots:		<b>4</b>	
Std Dev:	<b>21 ft/s</b>	<b>7 m/s</b>	Spread:		<b>48 ft/s</b>	<b>15 m/s</b>
ZMR:	<b>6 ft/s</b>	<b>2 m/s</b>				
Striking Velocity (ft/s)	Gamma (m/s)	Result (deg)	Used for V <sub>50</sub> (Yes/No)	Shot Number	Comments	
2141	653	--	CP	No		
<b>2055</b>	<b>626</b>	--	<b>CP</b>	<b>Yes</b>	<b>13833</b>	
1860	567	--	PP	No	13834	
2009	612	--	PP	No	13835	
<b>2061</b>	<b>628</b>	--	<b>PP</b>	<b>Yes</b>	<b>13836</b>	
1971	601	--	PP	No	13837	
2008	612	--	PP	No	13838	
2027	618	--	PP	No	13839	
2131	649	--	CP	No	13840	
<b>2095</b>	<b>639</b>	--	<b>CP</b>	<b>Yes</b>	<b>13841</b>	
<b>2047</b>	<b>624</b>	--	<b>PP</b>	<b>Yes</b>	<b>13842</b>	

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Target:	<b>7056-T751</b>			Date:	<b>12/11/2014</b>	
Plate Number:	<b>647921</b>			Location:	<b>EF 106</b>	
Thickness, in:	<b>1.638</b>					
Thickness, mm:	<b>41.61</b>					
Hardness, BHN:	<b>156</b>					
Oblliquity:	<b>0°</b>					
Projectile:	<b>0.30-cal APM2</b>					
Velocity Measurement:	<b>Chronograph</b>					
V <sub>50</sub> :	<b>3023 ft/s</b>	<b>922 m/s</b>		Number of Shots:	<b>4</b>	
Std Dev:	<b>25 ft/s</b>	<b>8 m/s</b>		Spread:	<b>55 ft/s</b>	<b>17 m/s</b>
ZMR:	<b>N/A</b>	<b>N/A</b>				
Striking Velocity (ft/s)	Gamma (m/s)	Result (deg)		Used for V <sub>50</sub> (Yes/No)	Shot Number	Comments
2729	832	--	PP	No	14090	
2998	914	--	PP	No	14091	
3146	959	--	CP	No	14092	
2885	879	--	PP	No	14093	
<b>3005</b>	<b>916</b>	--	<b>PP</b>	<b>Yes</b>	<b>14094</b>	
<b>3060</b>	<b>933</b>	--	<b>CP</b>	<b>Yes</b>	<b>14095</b>	
<b>3016</b>	<b>919</b>	--	<b>CP</b>	<b>Yes</b>	<b>14096</b>	
<b>3012</b>	<b>918</b>	--	<b>PP</b>	<b>Yes</b>	<b>14097</b>	

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Target:	<b>7056-T751</b>			Date:	<b>8/28/2014</b>	
Plate Number:	<b>647921</b>			Location:	<b>EF 106</b>	
Thickness, in:	<b>1.449</b>					
Thickness, mm:	<b>36.80</b>					
Hardness, BHN:	<b>166</b>					
Oblliquity:	<b>0°</b>					
Projectile:	<b>0.30-cal APM2</b>					
Velocity Measurement:	<b>Chronograph</b>					
V <sub>50</sub> :	<b>2797 ft/s</b>	<b>853 m/s</b>		Number of Shots:	<b>4</b>	
Std Dev:	<b>15 ft/s</b>	<b>5 m/s</b>		Spread:	<b>35 ft/s</b>	<b>11 m/s</b>
ZMR:	<b>N/A</b>	<b>N/A</b>				
Striking Velocity (ft/s)	Gamma (m/s)	Result (deg)	Used for V <sub>50</sub> (Yes/No)	Shot Number	Comments	
2688	819	--	PP	No	13851	
<b>2800</b>	<b>853</b>	<b>--</b>	<b>PP</b>	<b>Yes</b>	<b>13852</b>	
2902	884	--	CP	No	13853	
2841	866	--	CP	No	13854	
2853	870	--	CP	No	13855	
<b>2811</b>	<b>857</b>	<b>--</b>	<b>CP</b>	<b>Yes</b>	<b>13856</b>	
<b>2801</b>	<b>854</b>	<b>--</b>	<b>CP</b>	<b>Yes</b>	<b>13857</b>	
<b>2776</b>	<b>846</b>	<b>--</b>	<b>PP</b>	<b>Yes</b>	<b>13858</b>	

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Target:	<b>7056-T721</b>			Date:	<b>4/23/2015</b>	
Plate Number:	<b>649471</b>			Location:	<b>EF 106</b>	
Thickness, in:	<b>0.892</b>					
Thickness, mm:	<b>22.66</b>					
Hardness, BHN:	<b>153</b>					
Oblliquity:	<b>0°</b>					
Projectile:	<b>0.30-cal APM2</b>					
Velocity Measurement:	<b>Chronograph</b>					
V <sub>50</sub> :	<b>2161 ft/s</b>	<b>659 m/s</b>	Number of Shots:		<b>4</b>	
Std Dev:	<b>18 ft/s</b>	<b>5 m/s</b>	Spread:		<b>42 ft/s</b>	<b>13 m/s</b>
ZMR:	<b>N/A</b>	<b>N/A</b>				
Striking Velocity (ft/s)	Gamma (m/s)	Result (deg)	Used for V <sub>50</sub> (Yes/No)	Shot Number	Comments	
2048	624	--	PP	No		
2321	707	--	CP	No	14309	
2232	680	--	CP	No	14310	
2098	639	--	PP	No	14311	
2238	682	--	CP	No	14312	
<b>2157</b>	<b>657</b>	--	<b>PP</b>	<b>Yes</b>	<b>14313</b>	
2234	681	--	CP	No	14314	
<b>2166</b>	<b>660</b>	--	<b>CP</b>	<b>Yes</b>	<b>14315</b>	
<b>2182</b>	<b>665</b>	--	<b>CP</b>	<b>Yes</b>	<b>14316</b>	
<b>2140</b>	<b>652</b>	--	<b>PP</b>	<b>Yes</b>	<b>14317</b>	

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Target:	<b>7056-T721</b>			Date:	<b>4/16/2015</b>	
Plate Number:	<b>649461</b>			Location:	<b>EF 106</b>	
Thickness, in:	<b>1.613</b>					
Thickness, mm:	<b>40.97</b>					
Hardness, BHN:	<b>143</b>					
Oblliquity:	<b>0°</b>					
Projectile:	<b>0.30-cal APM2</b>					
Velocity Measurement:	<b>Chronograph</b>					
V <sub>50</sub> :	<b>2929 ft/s</b>	<b>893 m/s</b>		Number of Shots:	<b>4</b>	
Std Dev:	<b>19 ft/s</b>	<b>6 m/s</b>		Spread:	<b>39 ft/s</b>	<b>12 m/s</b>
ZMR:	<b>N/A</b>	<b>N/A</b>				
Striking Velocity (ft/s)	Gamma (m/s)	Result (deg)		Used for V <sub>50</sub> (Yes/No)	Shot Number	Comments
3066	934	--	CP	No	14291	
2994	913	--	CP	No	14292	
2810	856	--	PP	No	14293	
<b>2917</b>	<b>889</b>	--	<b>PP</b>	<b>Yes</b>	<b>14294</b>	
<b>2956</b>	<b>901</b>	--	<b>CP</b>	<b>Yes</b>	<b>14295</b>	
<b>2925</b>	<b>891</b>	--	<b>CP</b>	<b>Yes</b>	<b>14296</b>	
<b>2917</b>	<b>889</b>	--	<b>PP</b>	<b>Yes</b>	<b>14297</b>	

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## 0.50-cal APM2

Target:	<b>7056-T751</b>			Date:	<b>9/8/2014</b>	
Plate Number:	<b>933181</b>			Location:	<b>EF 108</b>	
Thickness, in:	<b>2.443</b>					
Thickness, mm:	<b>62.05</b>					
Hardness, BHN:	<b>156</b>					
Obliquity:	<b>0°</b>					
Projectile:	<b>0.50 cal APM2</b>					
Velocity Measurement:	<b>X-Ray</b>					
V <sub>50</sub> :	<b>2792 ft/s</b>	<b>851 m/s</b>		Number of Shots:	<b>4</b>	
Std Dev:	<b>22 ft/s</b>	<b>7 m/s</b>		Spread:	<b>47 ft/s</b>	<b>15 m/s</b>
ZMR:	<b>N/A</b>	<b>N/A</b>				
Striking Velocity (ft/s)	Gamma (m/s)	Result (deg)	Used for V <sub>50</sub> (Yes/No)	Shot Number	Comments	
2847	868	0.89	CP	No	12233	
<b>2770</b>	<b>844</b>	<b>0.59</b>	<b>PP</b>	<b>Yes</b>	<b>12234</b>	
<b>2817</b>	<b>859</b>	<b>0.74</b>	<b>CP</b>	<b>Yes</b>	<b>12235</b>	
<b>2802</b>	<b>854</b>	<b>0.05</b>	<b>CP</b>	<b>Yes</b>	<b>12236</b>	
2743	836	0.70	PP	No	12237	
<b>2778</b>	<b>847</b>	<b>1.28</b>	<b>PP</b>	<b>Yes</b>	<b>12238</b>	

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Target:	7056-T751			Date:	9/9/2014	
Plate Number:	933181			Location:	EF 108	
Thickness, in:	2.495					
Thickness, mm:	63.37					
Hardness, BHN:	156					
Oblliquity:	0°					
Projectile:	0.50 cal APM2					
Velocity Measurement:	X-Ray					
V <sub>50</sub> :	2845 ft/s	867 m/s		Number of Shots:	6	
Std Dev:	29 ft/s	9 m/s		Spread:	71 ft/s	22 m/s
ZMR:	7 ft/s	3 m/s				
Striking Velocity (ft/s)	Gamma (m/s)	Result (deg)	Used for V <sub>50</sub> (Yes/No)	Shot Number	Comments	
2886	880	0.64	CP	Yes	12239	
2843	867	0.70	PP	Yes	12240	
2875	876	0.74	CP	Yes	12241	
2817	859	0.96	PP	Yes	12242	
2815	858	0.81	PP	Yes	12243	
2836	864	0.69	CP	Yes	12244	

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Target:	7056-T751			Date:	9/3/2014	
Plate Number:	647921			Location:	EF 108	
Thickness, in:	1.638					
Thickness, mm:	41.61					
Hardness, BHN:	156					
Oblliquity:	0°					
Projectile:	0.50 cal APM2					
Velocity Measurement:	X-Ray					
V <sub>50</sub> :	2218 ft/s	676 m/s		Number of Shots:	6	
Std Dev:	30 ft/s	9 m/s		Spread:	83 ft/s	25 m/s
ZMR:	N/A	N/A				
Striking Velocity (ft/s)	Gamma (m/s)	Result (deg)	Used for V <sub>50</sub> (Yes/No)	Shot Number	Comments	
2219	676	0.40	CP	Yes	12226	
2165	660	0.60	PP	No	12227	
2203	671	0.86	PP	Yes	12228	
2262	689	0.44	CP	Yes	12229	
2242	683	0.67	CP	Yes	12230	
2179	664	0.36	PP	Yes	12231	
2201	671	0.62	PP	Yes	12232	

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Target:	<b>7056-T721</b>			Date:	<b>3/31/2015</b>	
Plate Number:	<b>649461</b>			Location:	<b>EF 108</b>	
Thickness, in:	<b>1.445</b>					
Thickness, mm:	<b>36.70</b>					
Hardness, BHN:	<b>143</b>					
Oblliquity:	<b>0°</b>					
Projectile:	<b>0.50 cal APM2</b>					
Velocity Measurement:	<b>X-Ray</b>					
V <sub>50</sub> :	<b>2050 ft/s</b>	<b>625 m/s</b>		Number of Shots:	<b>4</b>	
Std Dev:	<b>24 ft/s</b>	<b>8 m/s</b>		Spread:	<b>55 ft/s</b>	<b>17 m/s</b>
ZMR:	<b>N/A</b>	<b>N/A</b>				
Striking Velocity (ft/s)	Gamma (m/s)	Result (deg)		Used for V <sub>50</sub> (Yes/No)	Shot Number	Comments
2142	653	0.70	CP	No	12615	
<b>2052</b>	<b>625</b>	<b>1.14</b>	<b>PP</b>	<b>Yes</b>	<b>12616</b>	
2107	642	1.01	CP	No	12617	
2096	639	0.89	CP	No	12618	
<b>2070</b>	<b>631</b>	<b>0.49</b>	<b>CP</b>	<b>Yes</b>	<b>12619</b>	
1934	589	1.16	PP	No	12620	
1978	603	0.91	PP	No	12621	
<b>2015</b>	<b>614</b>	<b>0.40</b>	<b>PP</b>	<b>Yes</b>	<b>12622</b>	
<b>2063</b>	<b>629</b>	<b>0.78</b>	<b>CP</b>	<b>Yes</b>	<b>12623</b>	

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Target:	<b>7056-T721</b>			Date:	<b>2/25/2015</b>	
Plate Number:	<b>936221</b>			Location:	<b>EF 108</b>	
Thickness, in:	<b>2.569</b>					
Thickness, mm:	<b>65.25</b>					
Hardness, BHN:	<b>146</b>					
Oblliquity:	<b>0°</b>					
Projectile:	<b>0.50 cal APM2</b>					
Velocity Measurement:	<b>X-Ray</b>					
V <sub>50</sub> :	<b>2882 ft/s</b>	<b>879 m/s</b>		Number of Shots:	<b>4</b>	
Std Dev:	<b>29 ft/s</b>	<b>9 m/s</b>		Spread:	<b>57 ft/s</b>	<b>17 m/s</b>
ZMR:	<b>N/A</b>	<b>N/A</b>				
Striking Velocity (ft/s)	Gamma (m/s)	Result (deg)		Used for V <sub>50</sub> (Yes/No)	Shot Number	Comments
2698	822	0.53	PP	No	12555	
2751	838	1.47	PP	No	12556	
<b>2910</b>	<b>887</b>	<b>0.97</b>	<b>CP</b>	<b>Yes</b>	<b>12557</b>	
<b>2853</b>	<b>870</b>	<b>0.41</b>	<b>PP</b>	<b>Yes</b>	<b>12558</b>	
<b>2861</b>	<b>872</b>	<b>0.83</b>	<b>PP</b>	<b>Yes</b>	<b>12559</b>	
<b>2904</b>	<b>885</b>	<b>1.03</b>	<b>CP</b>	<b>Yes</b>	<b>12560</b>	

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Target:	7056-T721			Date:	2/23/2015	
Plate Number:	936231			Location:	EF 108	
Thickness, in:	2.572					
Thickness, mm:	65.33					
Hardness, BHN:	153					
Obliquity:	0°					
Projectile:	0.50 cal APM2					
Velocity Measurement:	X-Ray					
V <sub>50</sub> :	2809 ft/s	856 m/s		Number of Shots:	6	
Std Dev:	32 ft/s	10 m/s		Spread:	72 ft/s	22 m/s
ZMR:	N/A	N/A				
Striking Velocity (ft/s)	Gamma (m/s)	Result (deg)	Used for V <sub>50</sub> (Yes/No)	Shot Number	Comments	
2899	884	0.71	CP	No	12548	
2841	866	0.99	CP	Yes	12549	
2769	844	0.32	PP	Yes	12550	
2773	845	0.47	PP	Yes	12551	
2830	863	0.72	CP	Yes	12552	
2835	864	1.18	CP	Yes	12553	
2807	856	0.23	PP	Yes	12554	

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Target:	<b>7056-T751</b>			Date:	<b>2/4/2015</b>	
Plate Number:	<b>933171</b>			Location:	<b>EF 108</b>	
Thickness, in:	<b>3.006</b>					
Thickness, mm:	<b>76.35</b>					
Hardness, BHN:	<b>149</b>					
Oblliquity:	<b>0°</b>					
Projectile:	<b>0.50 cal APM2</b>					
Velocity Measurement:	<b>X-Ray</b>					
V <sub>50</sub> :	<b>3121 ft/s</b>	<b>951 m/s</b>		Number of Shots:	<b>4</b>	
Std Dev:	<b>12 ft/s</b>	<b>4 m/s</b>		Spread:	<b>26 ft/s</b>	<b>8 m/s</b>
ZMR:	<b>N/A</b>	<b>N/A</b>				
Striking Velocity (ft/s)	Gamma (m/s)	Result (deg)	Used for V <sub>50</sub> (Yes/No)	Shot Number	Comments	
3038	926	0.29	PP	No	12518	
<b>3135</b>	<b>956</b>	<b>0.34</b>	<b>CP</b>	<b>Yes</b>	<b>12519</b>	
3065	934	1.22	PP	No	12520	
<b>3109</b>	<b>948</b>	<b>0.77</b>	<b>PP</b>	<b>Yes</b>	<b>12521</b>	
3222	982	0.92	CP	No	12522	
2705	824	0.49	PP	No	12523	
3213	979	1.22	CP	No	12524	
3177	968	0.50	CP	No	12525	
<b>3125</b>	<b>952</b>	<b>0.70</b>	<b>CP</b>	<b>Yes</b>	<b>12526</b>	
<b>3114</b>	<b>949</b>	<b>0.67</b>	<b>PP</b>	<b>Yes</b>	<b>12527</b>	

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Target:	7056-T751			Date:	2/2/2015	
Plate Number:	933171			Location:	EF 108	
Thickness, in:	2.940					
Thickness, mm:	74.68					
Hardness, BHN:	153					
Oblliquity:	0°					
Projectile:	0.50 cal APM2					
Velocity Measurement:	X-Ray					
V <sub>50</sub> :	3102 ft/s	945 m/s		Number of Shots:	4	
Std Dev:	20 ft/s	6 m/s		Spread:	43 ft/s	13 m/s
ZMR:	N/A	N/A				
Striking Velocity (ft/s)	Gamma (m/s)	Result (deg)	Used for V <sub>50</sub> (Yes/No)	Shot Number	Comments	
2996	913	0.70	PP	No	12510	
3022	921	0.88	PP	No	12511	
3186	971	0.97	CP	No	12512	
<b>3101</b>	<b>945</b>	<b>0.84</b>	<b>CP</b>	<b>Yes</b>	<b>12513</b>	
3070	936	0.48	PP	No	12514	
<b>3089</b>	<b>941</b>	<b>0.79</b>	<b>PP</b>	<b>Yes</b>	<b>12515</b>	
<b>3088</b>	<b>941</b>	<b>0.72</b>	<b>PP</b>	<b>Yes</b>	<b>12516</b>	
3131	954	1.01	CP	Yes	12517	

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14.5-mm BS41

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Target:	<b>7056-T751</b>			Date:	<b>11/20/2014</b>	
Plate Number:	<b>933181</b>			Location:	<b>EF 106</b>	
Thickness, in:	<b>2.443</b>					
Thickness, mm:	<b>62.05</b>					
Hardness, BHN:	<b>156</b>					
Oblliquity:	<b>0°</b>					
Projectile:	<b>14.5-mm BS41</b>					
Velocity Measurement:	<b>X-Ray</b>					
V <sub>50</sub> :	<b>2624 ft/s</b>	<b>800 m/s</b>		Number of Shots:	<b>4</b>	
Std Dev:	<b>21 ft/s</b>	<b>6 m/s</b>		Spread:	<b>49 ft/s</b>	<b>15 m/s</b>
ZMR:	<b>N/A</b>	<b>N/A</b>				
Striking Velocity (ft/s)	Gamma (m/s)	Result (deg)		Used for V <sub>50</sub> (Yes/No)	Shot Number	Comments
2569	783	0.69	PP	No	14056	
2698	822	0.65	CP	No	14057	
<b>2648</b>	<b>807</b>	<b>1.55</b>	<b>CP</b>	<b>Yes</b>	<b>14058</b>	
2584	788	0.78	PP	No	14059	
<b>2633</b>	<b>802</b>	<b>0.56</b>	<b>CP</b>	<b>Yes</b>	<b>14060</b>	
<b>2599</b>	<b>792</b>	<b>0.73</b>	<b>PP</b>	<b>Yes</b>	<b>14061</b>	
<b>2615</b>	<b>797</b>	<b>0.99</b>	<b>PP</b>	<b>Yes</b>	<b>14062</b>	

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Target:	7056-T751			Date:	12/1/2014	
Plate Number:	933171			Location:	EF 106	
Thickness, in:	2.940					
Thickness, mm:	74.68					
Hardness, BHN:	153					
Oblliquity:	0°					
Projectile:	14.5-mm BS41					
Velocity Measurement:	X-Ray					
V <sub>50</sub> :	2866 ft/s	873 m/s		Number of Shots:	4	
Std Dev:	25 ft/s	8 m/s		Spread:	46 ft/s	14 m/s
ZMR:	N/A	N/A				
Striking Velocity (ft/s)	Gamma (m/s)	Result (deg)		Used for V <sub>50</sub> (Yes/No)	Shot Number	Comments
3108	947	0.60	CP	No	14067	
3028	923	3.20	CP	No	14068	High Yaw
2996	913	1.39	CP	No	14069	
<b>2888</b>	<b>880</b>	<b>1.57</b>	<b>CP</b>	<b>Yes</b>	<b>14070</b>	
2786	849	0.79	PP	No	14071	
2804	855	0.78	PP	No	14072	
<b>2842</b>	<b>866</b>	<b>1.39</b>	<b>PP</b>	<b>Yes</b>	<b>14073</b>	
<b>2846</b>	<b>867</b>	<b>1.12</b>	<b>PP</b>	<b>Yes</b>	<b>14074</b>	
<b>2888</b>	<b>880</b>	<b>1.16</b>	<b>CP</b>	<b>Yes</b>	<b>14075</b>	

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## 0.50-cal FSP

Target:	<b>7056-T751</b>			Date:	<b>9/24/2014</b>	
Plate Number:	<b>647911</b>			Location:	<b>EF 106</b>	
Thickness, in:	<b>0.900</b>					
Thickness, mm:	<b>22.86</b>					
Hardness, BHN:	<b>159</b>					
Obliquity:	<b>0°</b>					
Projectile:	<b>0.50-cal FSP</b>					
Velocity Measurement:	<b>Chronograph</b>					
V <sub>50</sub> :	<b>2623 ft/s</b>	<b>799 m/s</b>	Number of Shots:		<b>10</b>	
Std Dev:	<b>60 ft/s</b>	<b>18 m/s</b>	Spread:		<b>187 ft/s</b>	<b>57 m/s</b>
ZMR:	<b>187 ft/s</b>	<b>57 m/s</b>				
Striking Velocity (ft/s)	Gamma (m/s)	Result (PP/CP) (deg)	Used for V <sub>50</sub> (Yes/No)	Shot Number	Comments	
<b>2603</b>	<b>793</b>	--	<b>CP</b>	<b>Yes</b>	<b>13858</b>	
2451	747	--	PP	No	13859	
2468	752	--	PP	No	13860	
<b>2503</b>	<b>763</b>	--	<b>CP</b>	<b>Yes</b>	<b>13861</b>	
2501	762	--	PP	No	13862	
2521	768	--	PP	No	13863	
2510	765	--	PP	No	13864	
2539	774	--	PP	No	13865	
2550	777	--	PP	No	13866	
<b>2563</b>	<b>781</b>	--	<b>PP</b>	<b>Yes</b>	<b>13867</b>	
<b>2604</b>	<b>794</b>	--	<b>PP</b>	<b>Yes</b>	<b>13868</b>	
<b>2690</b>	<b>820</b>	--	<b>CP</b>	<b>Yes</b>	<b>13869</b>	
<b>2623</b>	<b>799</b>	--	<b>CP</b>	<b>Yes</b>	<b>13870</b>	
<b>2615</b>	<b>797</b>	--	<b>PP</b>	<b>Yes</b>	<b>13871</b>	
<b>2648</b>	<b>807</b>	--	<b>PP</b>	<b>Yes</b>	<b>13872</b>	
<b>2690</b>	<b>820</b>	--	<b>PP</b>	<b>Yes</b>	<b>13873</b>	
<b>2686</b>	<b>819</b>	--	<b>CP</b>	<b>Yes</b>	<b>13874</b>	

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Target:	<b>7056-T751</b>			Date:	<b>12/17/2014</b>	
Plate Number:	<b>647911</b>			Location:	<b>EF 106</b>	
Thickness, in:	<b>1.024</b>					
Thickness, mm:	<b>26.01</b>					
Hardness, BHN:	<b>156</b>					
Obliquity:	<b>0°</b>					
Projectile:	<b>0.50-cal FSP</b>					
Velocity Measurement:	<b>Chronograph</b>					
V <sub>50</sub> :	<b>3607 ft/s</b>	<b>1100 m/s</b>		Number of Shots:	<b>4</b>	
Std Dev:	<b>18 ft/s</b>	<b>5 m/s</b>		Spread:	<b>36 ft/s</b>	<b>11 m/s</b>
ZMR:	<b>24 ft/s</b>	<b>7 m/s</b>				
Striking Velocity (ft/s)	Gamma (m/s)	Result (deg)	Used for V <sub>50</sub> (Yes/No)	Shot Number	Comments	
3249	990	--	PP	No		
3308	1008	--	PP	No		
<b>3593</b>	<b>1095</b>	<b>--</b>	<b>PP</b>	<b>Yes</b>		
3902	1189	--	CP	No		
3505	1068	--	PP	No		
3881	1183	--	CP	No		
3764	1147	--	CP	No		
3848	1173	--	CP	No		
3675	1120	--	CP	No		
<b>3592</b>	<b>1095</b>	<b>--</b>	<b>CP</b>	<b>Yes</b>		
<b>3628</b>	<b>1106</b>	<b>--</b>	<b>CP</b>	<b>Yes</b>		
3649	1112	--	CP	No		
3547	1081	--	PP	No		
<b>3616</b>	<b>1102</b>	<b>--</b>	<b>PP</b>	<b>Yes</b>		

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Target:	<b>7056-T721</b>			Date:	<b>1/7/2015</b>	
Plate Number:	<b>649471</b>			Location:	<b>EF 106</b>	
Thickness, in:	<b>0.894</b>					
Thickness, mm:	<b>22.71</b>					
Hardness, BHN:	<b>153</b>					
Oblliquity:	<b>0°</b>					
Projectile:	<b>0.50-cal FSP</b>					
Velocity Measurement:	<b>Chronograph</b>					
V <sub>50</sub> :	<b>3140 ft/s</b>	<b>957 m/s</b>	Number of Shots:		<b>4</b>	
Std Dev:	<b>18 ft/s</b>	<b>5 m/s</b>	Spread:		<b>42 ft/s</b>	<b>13 m/s</b>
ZMR:	<b>N/A</b>	<b>N/A</b>				
Striking Velocity (ft/s)	Gamma (m/s)	Result (deg)	Used for V <sub>50</sub> (Yes/No)	Shot Number	Comments	
2559	780	--	PP	No		
2823	860	--	PP	No	14113	
3211	979	--	CP	No	14114	
3021	921	--	PP	No	14115	
<b>3163</b>	<b>964</b>	--	<b>CP</b>	<b>Yes</b>	<b>14116</b>	
<b>3133</b>	<b>955</b>	--	<b>PP</b>	<b>Yes</b>	<b>14117</b>	
3170	966	--	CP	No	14118	
<b>3141</b>	<b>957</b>	--	<b>CP</b>	<b>Yes</b>	<b>14119</b>	
<b>3121</b>	<b>951</b>	--	<b>PP</b>	<b>Yes</b>	<b>14120</b>	

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## 20-mm FSP

Target:	<b>7056-T751</b>			Date:	<b>10/22/2014</b>	
Plate Number:	<b>647921</b>			Location:	<b>EF 108</b>	
Thickness, in:	<b>1.638</b>					
Thickness, mm:	<b>41.61</b>					
Hardness, BHN:	<b>156</b>					
Obliquity:	<b>0°</b>					
Projectile:	<b>20-mm FSP</b>					
Velocity Measurement:	<b>Chronograph</b>					
V <sub>50</sub> :	<b>3319 ft/s</b>	<b>1012 m/s</b>	Number of Shots:		<b>4</b>	
Std Dev:	<b>8 ft/s</b>	<b>2 m/s</b>	Spread:		<b>17 ft/s</b>	<b>5 m/s</b>
ZMR:	<b>N/A</b>	<b>N/A</b>				
Striking Velocity (ft/s)	Gamma (m/s)	Result (deg)	Used for V <sub>50</sub> (Yes/No)	Shot Number	Comments	
<b>3323</b>	<b>1013</b>	--	<b>PP</b>	<b>Yes</b>		
3419	1042	--	CP	No	12356	
3373	1028	--	CP	No	12357	
<b>3328</b>	<b>1014</b>	--	<b>CP</b>	<b>Yes</b>	<b>12358</b>	
<b>3314</b>	<b>1010</b>	--	<b>CP</b>	<b>Yes</b>	<b>12359</b>	
<b>3311</b>	<b>1009</b>	--	<b>PP</b>	<b>Yes</b>	<b>12360</b>	

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Target:	<b>7056-T751</b>			Date:	<b>10/24/2014</b>	
Plate Number:	<b>647921</b>			Location:	<b>EF 108</b>	
Thickness, in:	<b>1.449</b>					
Thickness, mm:	<b>36.80</b>					
Hardness, BHN:	<b>166</b>					
Oblliquity:	<b>0°</b>					
Projectile:	<b>20-mm FSP</b>					
Velocity Measurement:	<b>Chronograph</b>					
V <sub>50</sub> :	<b>2479 ft/s</b>	<b>756 m/s</b>		Number of Shots:	<b>6</b>	
Std Dev:	<b>35 ft/s</b>	<b>11 m/s</b>		Spread:	<b>84 ft/s</b>	<b>26 m/s</b>
ZMR:	<b>26 ft/s</b>	<b>8 m/s</b>				
Striking Velocity (ft/s)	Gamma (m/s)	Result (deg)	Used for V <sub>50</sub> (Yes/No)	Shot Number	Comments	
2568	783	--	CP	No	12361	
<b>2506</b>	<b>764</b>	--	<b>PP</b>	<b>Yes</b>	<b>12362</b>	
2586	788	--	CP	No	12363	
2543	775	--	CP	No	12364	
2528	770	--	CP	No	12365	
2521	768	--	CP	No	12366	
2541	774	--	CP	No	12367	
<b>2494</b>	<b>760</b>	--	<b>CP</b>	<b>Yes</b>	<b>12368</b>	
<b>2480</b>	<b>756</b>	--	<b>CP</b>	<b>Yes</b>	<b>12369</b>	
2629	801	--	CP	No	12370	
<b>2520</b>	<b>768</b>	--	<b>CP</b>	<b>Yes</b>	<b>12371</b>	
<b>2437</b>	<b>743</b>	--	<b>PP</b>	<b>Yes</b>	<b>12372</b>	
<b>2436</b>	<b>742</b>	--	<b>PP</b>	<b>Yes</b>	<b>12373</b>	

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Target:	<b>7056-T721</b>			Date:	<b>3/30/2015</b>	
Plate Number:	<b>649471</b>			Location:	<b>EF 106</b>	
Thickness, in:	<b>0.892</b>					
Thickness, mm:	<b>22.66</b>					
Hardness, BHN:	<b>153</b>					
Oblliquity:	<b>0°</b>					
Projectile:	<b>20-mm FSP</b>					
Velocity Measurement:	<b>X-ray</b>					
V <sub>50</sub> :	<b>1329 ft/s</b>	<b>405 m/s</b>		Number of Shots:	<b>4</b>	
Std Dev:	<b>23 ft/s</b>	<b>7 m/s</b>		Spread:	<b>55 ft/s</b>	<b>17 m/s</b>
ZMR:	<b>7 ft/s</b>	<b>2 m/s</b>				
Striking Velocity (ft/s)	Gamma (m/s)	Result (deg)	Used for V <sub>50</sub> (Yes/No)	Shot Number	Comments	
1417	432	0.30	CP	No	14251	
<b>1322</b>	<b>403</b>	<b>1.83</b>	<b>CP</b>	<b>Yes</b>	<b>14252</b>	
1236	377	0.86	PP	No	14253	
1256	383	0.70	PP	No	14254	
--	--	--	PP	No	14255	missed x-ray
1286	392	1.44	PP	No	14256	
<b>1305</b>	<b>398</b>	<b>0.69</b>	<b>PP</b>	<b>Yes</b>	<b>14257</b>	
<b>1329</b>	<b>405</b>	<b>0.34</b>	<b>PP</b>	<b>Yes</b>	<b>14258</b>	
<b>1360</b>	<b>415</b>	<b>1.75</b>	<b>CP</b>	<b>Yes</b>	<b>14259</b>	

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Target:	<b>7056-T721</b>			Date:	<b>3/23/2015</b>	
Plate Number:	<b>649461</b>			Location:	<b>EF 106</b>	
Thickness, in:	<b>1.445</b>					
Thickness, mm:	<b>36.70</b>					
Hardness, BHN:	<b>143</b>					
Oblliquity:	<b>0°</b>					
Projectile:	<b>20-mm FSP</b>					
Velocity Measurement:	<b>X-ray</b>					
V <sub>50</sub> :	<b>2868 ft/s</b>	<b>874 m/s</b>		Number of Shots:	<b>4</b>	
Std Dev:	<b>22 ft/s</b>	<b>7 m/s</b>		Spread:	<b>49 ft/s</b>	<b>15 m/s</b>
ZMR:	<b>N/A</b>	<b>N/A</b>				
Striking Velocity (ft/s)	Gamma (m/s)	Result (deg)		Used for V <sub>50</sub> (Yes/No)	Shot Number	Comments
2544	775	1.23	PP	No	14241	
2613	796	1.08	PP	No	14242	
2672	814	0.77	PP	No	14243	
2768	844	0.51	PP	No	14244	
<b>2835</b>	<b>864</b>	<b>0.67</b>	<b>PP</b>	<b>Yes</b>	<b>14245</b>	
<b>2877</b>	<b>877</b>	<b>0.46</b>	<b>CP</b>	<b>Yes</b>	<b>14246</b>	
<b>2874</b>	<b>876</b>	<b>0.56</b>	<b>PP</b>	<b>Yes</b>	<b>14247</b>	
2819	859	0.89	PP	No	14248	
--	--	--	CP	No	14249	missed x-ray
<b>2884</b>	<b>879</b>	<b>0.98</b>	<b>CP</b>	<b>Yes</b>	<b>14250</b>	

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Target:	<b>7056-T721</b>			Date:	<b>2/19/2015</b>	
Plate Number:	<b>649461</b>			Location:	<b>EF 106</b>	
Thickness, in:	<b>1.613</b>					
Thickness, mm:	<b>40.97</b>					
Hardness, BHN:	<b>143</b>					
Obliquity:	<b>0°</b>					
Projectile:	<b>20-mm FSP</b>					
Velocity Measurement:	<b>X-ray</b>					
V <sub>50</sub> :	<b>3376 ft/s</b>	<b>1029 m/s</b>	Number of Shots:		<b>4</b>	
Std Dev:	<b>27 ft/s</b>	<b>8 m/s</b>	Spread:		<b>55 ft/s</b>	<b>17 m/s</b>
ZMR:	<b>N/A</b>	<b>N/A</b>				
Striking Velocity (ft/s)	Gamma (m/s)	Result (PP/CP) (deg)	Used for V <sub>50</sub> (Yes/No)	Shot Number	Comments	
3237	987	0.40	PP	No		
3468	1057	1.93	CP	No	14192	
3256	992	0.56	PP	No	14193	
3292	1003	0.55	PP	No	14194	
<b>3353</b>	<b>1022</b>	<b>1.55</b>	<b>PP</b>	<b>Yes</b>	<b>14195</b>	
<b>3388</b>	<b>1033</b>	<b>0.55</b>	<b>CP</b>	<b>Yes</b>	<b>14196</b>	
<b>3353</b>	<b>1022</b>	<b>0.57</b>	<b>PP</b>	<b>Yes</b>	<b>14197</b>	
3455	1053	0.18	CP	No	14198	
<b>3408</b>	<b>1039</b>	<b>0.66</b>	<b>CP</b>	<b>Yes</b>	<b>14199</b>	

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## **List of Symbols, Abbreviations, and Acronyms**

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AA	aluminum alloy
Al	aluminum
AP	armor-piercing
ARL	US Army Research Laboratory
CP	complete penetration
EF	experimental facility
FSP	fragment-simulating projectile
ID	identification
IR	infrared
mil-spec	military specification
PP	partial penetration

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